

Thesis for [Master of Science, cand.oecon, cand.polit] - degree.

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# **Analysis on the Economic Valuation of Ecosystem Services:**

*A case study on LuGu Lake basin*

**Ding Ding**

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**Department of Economics**

**University of Oslo**

## Preface

*From the start of my study at university of Oslo, I recognized my interesting in writing my thesis to the Master degree in one of the parts of Resource Economics and Ecology Economics and decided to carry on some quantitative analysis. Thus, it might be greater with providing common work for part of this project and emphasis on more comparative analysis with other related evaluations. Indeed, for information and insight I should grateful to my colleagues in China serviced in Academy of Macroeconomic Research Institute (NDRC), whose work has been of great value. Their response to my seeking help is always that fast. And needless to say, I have drawn heavily on my own of work in this area and would continue with it.*

*I must express my appreciation to my supervisor Gang Liu, for his inspiration in the thesis, grateful to him for his constructive suggestions, and sound treatment. His comments and the discussion with him are often full of illuminations which help me accomplish this thesis favorably. Thanks also to Professor Olav Bjerkholt, the director of Program in Environmental and Development Economic, which open another door to the students from developing countries. I will always remember the great effort which done to provide the best environment to us, students in the Master program. I would like to express my acknowledgement to him and thank him for all his efforts during my study time. These cherish experience would encourage me forever. Without the help and advice from all these people, I definitely could not go so far. But all remaining errors are of course my own responsibility.*

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## Abstract

This thesis is an empirical investigation and application of economic valuation of ecosystem in Lugu Lake, southern China.

**Ecosystem Services (ES)** and their quantitative assessment have become one of ecological economics research focuses since 1997, especially the **Economic Valuation of Ecosystem Services (EVES)**. An essential reason of the controversies is they are reviewed from different study angles. Different disciplinary paradigms lead to the debate that whether EVES study is necessary and different research scales lead to the debate related to theories, practical implications of different methodologies. It is necessary to systematically summarize present research viewpoints, methods and theoretic backgrounds of EVES. Based on the review of relating theories and case studies of EVES, this study summarized ecol-economics pre-analysis vision of EVES and compared contemporary theories, policy implications, appropriate methods and problems under research which are introduced in all kinds of literatures.

In this dissertation, research methodologies of EVES were classified into two systems: (1) Absolute economic valuation of ES, which focus on the whole contributions from ecosystem to society and economy. ES values are measured with material, energy or monetary units in these kinds of researches. Absolute ES economic values can reflect the material scarcity of natural capital and synthetic conditions of the whole ecol-economic systems, which can provide guidelines for the improvement of national accounting systems and social-economic development assessment. (2) Relative economic valuation of ES, which focus on partial contributions from ecosystem to society and economy and the appraisal results of these valuation are measured with monetary units. The short-term policy implications of relative ES economic valuation are more abundant than absolute ones because these kinds of research are more helpful for policy makers to make choices among different trade-offs and market

incentives, so policies and institutions can be designed according to them. As the case analysis, the paper discusses the economic valuation of ecosystem services of Lugu Lake basin.

The meaning of the ES and the theory that case analysis involved is discussed in Part 1; Part 2 analyze relevant basic theories separately, material analysis of ecosystem services, and method of EVES, sum up the general theory and policy meaning; Part 3-4 expound the fact that the economic evaluation and ecosystem services of Lugu Lake, the total economic value of the Lugu lake ecosystem is derived through aggregating the values from those different components; Placing the study area into a broader picture of whole Lugu Lake, the empirical research of Lugu Lake was carried out with fundamental market substitution methods for ecosystem services evaluation. Theoretically speaking, countable general equilibrium model is desirable to assess them; but data restriction and relevant chain feedbacks make it practically infeasible. Although the research seems simple, some theoretical implications can be revealed from the application of ecosystem services evaluations; Based on the economic valuation of ecosystem service, the thesis concludes with discussion of policy implications, Part 5 summarizes the result of the reckoned value of the services of the ecosystems of Lugu Lake areas, suggests enhancing the strategies and countermeasures to local sustainable development.

At policy and institutional level, interesting issues for further studies are how to protect the regional development and how economically develop the local economic growth, and so on. With respect to environmental economics in China, future studies include: How environmental valuation methods are applied in China? How economic valuation of ecosystem methods would be carried out in China? Enlarged economic evaluation of ecosystem services may be helpful for relative stakeholders who will take better and more public rational choices.



## **1. Introduction**

The environmental protection movement developed continuously within the scope of world since the second half of 20th century, at the same time, the concept of sustainable development was gradually deep-rooted among the people, the corresponding theories' investigation also been push forward continuously. Within the sustainable development theory, the ecology and the economic theory method is the foundation, and the evolution rule of complex ecology system is the research object, the new cross-discipline "the ecological economics" which integrates multi-kinds correlative disciplines of natural and social sciences becomes an important front research area. Because of the definition and analysis of ecosystem and sustainable development involve many kinds of theoretical disciplines and the various human social activities, the present fundamental research is not yet been established "the model-theory-policy" system. Researchers with different background have the different view, even more, opposite.

A basic common understanding that has already been formed at present is, close ties existed between economic system and ecosystem, and the ecological environment has made indispensable contribution to the economic development of human society. Benefit that human society obtained from the ecosystem mainly includes useful material and energy input, offal acceptance and transformation, which were general designed as **Ecosystem services (ES)** in recent years, enter social economic department, combine with artificial capital and manpower capital, then produce the final consumer goods, for example, the foundation supports function such as producing various kinds of raw materials and offering the source of water to regulate. It may also be directly enjoyed by individual member of human society, such as offering such comfortableness resources as clean air, bright view, etc. The natural ecosystem can be considered as the **Natural Capital (NC)**.

As the economic scope of mankind activities is being expanded constantly, ecosystem services and natural capital become the greatest limiting factor of social economic development nowadays. Gradually, improving the utilization efficiency of the natural capital becomes the important subject to be solved of sustainable development. The improvement of the utilization efficiency of the capital depends on the rising of its rate of return on investment. As the ecosystem services, the benefit output of natural capital, possess the characteristics of public good or the accurate public good more, unable to participate in normal marketing, this means natural capital investment and income are asymmetric, cause microeconomic subject maintain natural incentive mechanism of capital insufficient. Meanwhile, the natural capital has restrained public policy-making bodies from allocating public resources to the complexity of contributing mechanism of social economic development rationally. The meaning of study in **Economic Evaluation of the Ecosystem services (EVES)** lies in, express with the relative income that the monetary unit invests natural capital in, help the micro individual and public policymaker, compare different natural capital and non-natural capital investment, promote the utilization efficiency of the natural capital, to raise and strengthen social ability of realize sustainable development.

The economic evaluation of the ecosystem services became the highlight that ecologist and economist paid close attention to after 1997, issue at Nature " global ecological between service of the system and natural value of capital estimate " quote over the scientific and technological thesis of 375 within 5 years, my paper will review the progress briefly on the basis of defining theory normal form of ecological economics, sum up the latest research results that the economic evaluation material of ecosystem services correlated with economic relation, summarize theory model, method system and policy meaning of supply and demand simulation of the ecosystem services.

## 2. Theoretical and empirical literature on EVES

It is a study filled with controversy subject that the economic evaluation of the ecosystem service is, among them much dispute begins to disagree from the initial starting point, namely basic difference theories normal paradigm or pre-analytic vision. The importance is to analyze views and subjective matter (Schumpeter, 1954). Before discussing material base and interests relationship involved in economic evaluation of the ecosystem services, it is necessary to define the ecological economics normal form followed in this research, and corresponding natural capital meaning and value assessment angle at first.

### 2.1 Ecological economics and environmental economics

Before the concept of ecosystem services is explained in an all-round way (Daily, 1997; OuYang, 2002) the other kind of EVES developed under the cost-benefit analysis of the environmental impact. (Pearce and Turner, 1990) But from starting points, the concept of EVES and ecological economics are different, this is new developing ecological economics and also is the difference between **Ecological Economics (EE)** and traditional environment and **Environmental and Resource Economics (ERE)**.

The difference between EE and ERE lies in, at first, their angle and model of studying the ecology with dynamic economic system is different: The former regarded the economic system as the opening subsystem of ecosystem, appropriate in systematic scale with economy, public and owning resource allocation in common, operating the optimum standard; The latter is regarded the natural capital and ecosystem services as the factor of production, its primary goal is to operate effectively with the economic system, consider the fair problem of natural resource allocation partly.

EE and ERE launch at different scope and methods in carrying out the EVES, the former gives consideration to the ecosystem services, material rareness of the natural capital and economic rareness that can be transformed, assess all kinds of ecosystem services of the whole world, not only estimate the relative value of the ecosystem services, but also analyze the absolute magnitude of the ecosystem services; The latter

investigates especially those can enter the disposing and distribution cycle of ecosystem services of the economic trade system, and paid more attention to those can change rareness of material into economic rareness of the ecosystem services. Because of wider ranges that EE involve, it need more factors and even complicated relationship analysis among EVES, the research tool adopted is more various, the accuracy of the result and the logic tightness of research are not so good as ERE.

## **2.2 Value of ecosystem services**

The definition of the object are different, the value of the ecosystem services is also different. From different scale of economic system of the ecology, the ecosystem services have multiple values.

Because the ecosystem services comes from the structure and proceeding of the ecosystem, the ability that the ecosystem provides service to the social economic system usually has close relation to stability of the ecosystem, healthy contribution with the ecosystem component, it is suggested to use the concept of ecological value to compare and analysis the relation between parts of ecosystem (Farber, et al.,2002). If regarded economic system as a subsystem of the ecosystem, consider the contribution to economic system from other components of ecosystem, the ecosystem services of the assessment and support the function to various kinds of products offered, the focal would be the material amount of these services. This need to divide various kinds of ecological functions and ecological service of the system rationally, try to show them through a certain material index in unison, the content discussed in 2.3 of my dissertation.

Because the natural capital has substitutability, some material rareness of natural capital and ecosystem services can be turned into economic rareness, if from the angle within the economic system (include the investment and repayment of natural capital and non-natural capital) to investigate comparative value of the ecosystem (especially to as goods and the labor, market trading object), the value of ecosystem services will then equal to the relative economic value of these ecosystem services, usually use the monetary to weigh. The relative economic value of the ecosystem services not merely needs to analyze the ecosystem and its contribute to the economic system as the

foundation, but also need to correlate with social and economic situation of stakeholders.

### **2.3 Previous research on analysis of EVES**

The EVES needs to analyze the material output and function of the ecosystem structure as the foundation, to illustrate interaction between production mechanism of ES, so the production and classification of the ecological service of the system are essential components that EVES studies. At present, the efforts in this area are mainly studied for the economic assessment of global ecosystem, adopted index measurement of the currency media of exchange inside economic system, and other materials indexes too.

There are much methods of the ecosystem services, the one of great impact among them is divided from the usable way of the ecosystem (Daily, 1997; Moberg and Folke, 1999), ecosystem and economic support function way that system operate divide into function and corresponding service system (Costanza, et al., 1997; De Groot et al., 2002; MA, 2003), and according to producing the yardstick in ecosystem structure (Limburg, et al., 2002), according to the type of the ecosystem (UNDP, 2000), etc..

Moberg and Folke (1999) studied the ecosystem services of the coral reef, divide nature products to regenerated resources, non-renewable resources products, physical structure services, biotic services, biogeochemical services, information services and social and cultural services.

According to ecosystem structure function and production mechanism of ES, is the extensive way to classify the ES. Detailed ES classifies the research (De Groot et al, 2002) studied and divide the ecosystem services into the regulating function according to the regulation, habitat, production, about 23 sub classics. The United Nations "Millennium Ecosystem Assessment" (2000), especially categorised four function group make of provisioning services, regulating services, cultural services, and supporting services, according to the interaction method, among the ecosystem structure, function and ES,

## **2.4 Policy indication of materials analysis on EVES**

To avoid the repetition and omission phenomenon in quantitative evaluation of ecosystem, EVES need to investigate production mechanism, interaction of different eco system service of the ES, and carry on the proper classification to ES in view of the above. The existing representative methods mainly are: (1) The worth analysis from the total supply of ES;(2)The ecological footprint from the total demand of ES;(3)The expand comparative analysis of net flows among the sub-ecosystems.

Though it is not obvious that the meaning of research on the production mechanism and definitely economic evaluation of ecosystem services in short-term policy decision, but research work would contribute to strengthening the understanding of dynamic economic system of the ecosystem of the whole society, it would also offer a reference standard of appraising the relative economic worth of the ecosystem services, significance too in setting up a more scientific national economic and social development evaluation index system.

## **2.5 Brief summary**

My research adopts the relatively economic evaluation method, that is, at first, calculate the benefit of single kind of ES on unit's; then regard area of ecosystem ground of all kinds of as weight coefficient and adds it. This is a kind of preliminary static behavior, but we can draw result that point out the meaning and can avoid repeated. My research chose concrete evaluate target and the parameter cautiously, so as to ensure our assessment presses close to the actual market of China. Because the Lugu Lake increases yield directly the eco-environmental benefit and ecosystem and improves the eco-environmental benefit brought to overlap, but the former is easier to change at any time, the latter has steady and more extensive meaning. As it is not easy for all the ES can be evaluated in proper way, find a corresponding one can enter actual compensation way of market, so maybe some appraisal method and this result close to actual market but others relatively far from its real market value.

### **3. Analysis on Lugu Lake ecosystem services**

#### **3.1 Study site description**

Lugu Lake is located at the border of Sichuan and Yunnan Province. It is 72km north of Ninglang Town and is also under the control of both provinces. The lake is 2685 meters above sea level , 5.2km wide from east to west, and has an area of 48.5 square km. The deepest end of the lake is about 93.5 meters.

Lugu Lake is long and narrow, like a hoof filled with limpid water. Five small forested islands are interspersed across the surface, three of which are in Yunnan precinct. The smallest island is called Lige Island, and there are only eight Mosuo families living on it. Another island, called Chieftain Island, was named because Ayunshan, the chieftain of Yongning Village, had built a villa and lived here until his death in the Guangxu period of the Qing Dynasty. Simultaneously, Joseph Rock, an Austrian writer who was his friend, wrote part of the *Ancient Naxi Kingdom of South-west China* (Harvard University Press, 1947) on this island. Liwubi Island, which lies three kilometers (one point nine miles) away from Chieftain Island, is actually a small peninsula extended into the lake by the Holy Gemu Mountain. The mountain is also called Lion Mountain, for it looks like a lion drinking water beside the lake. Mosuo people believe that a beautiful and kind goddess named Gemu lives on the mountain and blesses the residents at all times. A great sacrificial rite is held to worship the goddess on July 25th of each lunar year at the foot of Gemu Mountain.

Lugu Lake has no industrial inputs but its watershed suffers from severe gully erosion and a decline of endemic fish populations. Scientific monitoring and research have played a limited role in Lugu Lake's management. A small amount of monitoring data was collected by the county environmental protection office, but was not shared with village level resource managers. Monitoring data and other scientific support from county agencies could help local resource managers determine the effects of increasing erosion on lake water quality and possible causes of the endemic fish catch

decline. Unfortunately, data quality tends to be poor at the county level and in places like Lugu Lake where people have little experience in monitoring water quality.

Many cultural sites and scenic spots are scattered along the lakeside. As one of the remaining matriarchal societies -Mosuo people and their customs are living fossils in a sense. In every family, according to the traditions of the matriarchate, women have the most important roles and they take on all the responsibilities of the families and the village. Children take the mothers' family names and live with their mothers. The relationship between the Mosuo lovers is called "Axia" instead of marriage in the common society. When the youth have gone through a Maturity Ceremony at the age of 13, they are permitted to choose their own Axia. Official procedures or documents are not needed here and the retaining time of this Axia relationship is based on the lovers' wishes. They are also Mosuo villages, plateau hot springs, the underground maze-The Lucky Cave, the Chieftain's Palace, the Zhamei Lamaist Temple, Riyuehe - The Ruins of the Yuan Army Quarters when Kublai Khan was on his south - expansion, yongning - the key town on the ancient tea and horse trading route. Many beautiful legends have been circulating among the people. Thus the place is called "A Quaint Realm of Matriarchy".

There are basically no industries in Lugu Lake basin, and the agricultural economy takes the absolute superiority. The financial income mainly comes from first industry. However, tourism has great development in recent years (Table 1).

**Table 1 The economic development of Lugu Lake basin (2000)**

Province	Village/Town	Total Income (Yuan)	Primary Industrial Income (Yuan)	Proportion (%)	Third Industrial Income (Yuan)	Proportion (%)
Yunnan	Shankua	228900	215400	94	13500	6
	Puluo	248200	229900	93	18300	7
	Langfang	136030	128530	94	7500	6
	Wangjiawan	102655	98055	96	4600	4
	Lvjiaying	112915	106115	94	6800	6



	Sanjiacun	169430	155730	92	13700	8
	Luoshui	615994	270494	44	345500	56
	Zhudi	228723	213223	93	15500	7
	Lige	156270	125070	80	31200	20
	Small Luoshui	169230	156230	92	13000	8
	Laowuji	113060	106560	94	6500	6
	Subtotal	2281407	1805307	79	476100	21
Sichuan	Lugu	12860000	9683923	75	3176077	25
Total		15141407	11489230	76	3652177	24

**Source:** Lijiang Statistical Yearbook 2000 [C].Edit by Statistics Bureau of Yunnan Province .Kunming. 2001.

### 3.2 Natural resources

**Water resources.** According to the Report on Lugu Lake Valley Environmental Program drafted by the Yunnan Provincial Administration of Environmental Protection in 1998, the annual average water inflow into the lake is 126 million cubic meters, while the evaporation is 66 million cubic meters, presenting a net amount of water resources of 60 million cubic meters. Of this, the recoverable resources of water are 70% of the net amount, and the actual utilization of water resources of the lake stand at 42 million cubic meters. The figures match the dynamic water capacity of the lake in many years (the lowest water level of the lake: 2,689.8m, and the highest storage water level: 2,690.8m, with changing range of 1m). Thanks to the limited water resources, the lake is considered to be neither suitable for hydropower development, nor for large amount of water storage and discharge for electric power generation, which will lead to irrational falloff of water level, and bring about a string of problems concerning ecology and environment of the lake are. The conclusion is that the water resource of Lugu Lake is only suitable for irrigation of farmland and forestland, daily use and tourism.

**Forest resources.** According to statistics, forestlands in Lugu Lake basin in the part of Yunnan Province are about 46.3 square kilometers, with forest coverage standing at 47.6%, and live wood reserves of 320,000 cubic meters. Except the part of primeval

forests, most of the forests are grown with un-mature trees, and the mature forests reserves only account for 9% because of the damages by forest fire and denudation and disordered lumbering. The forestlands in Lugu Lake basin in the part of Sichuan Province, mainly in the six administrative villages, are 28.34 square kilometers, accounting for 18% of the total land in use. The lands in Pingba area of Yongningba Prefecture are most farmlands, and its surrounding areas are almost grassland or barren mountains.

The forest resources in the area are limited, and most of them are sparse forests and bushes. The existing mature forests reserves are small in amount, which can hardly be used for timber production. In particular, the area has been designated as a key area for protection of natural forests as it is on the upstream of the Yangtze River. The forests in the Lugu Lake valley shall be mainly used for water and soil conservation, not for timber production. At present, the macro scope of Lugu Lake is under slight to light erosion, with erosion modulus standing at 200-300 tons per square kilometers annually, and some areas are in poor geological condition and vegetation, posing big degree of erosion. The fan-shaped accumulations on the lakesides indicate the seriousness of the water and soil erosion in the area. Furthermore, once the vegetation of the primeval forests is damaged, the area is likely to be eaten up by the invasion of derivative biomes, turning highland willows, birches, poplar and dwarf bushes into grassland. The forests in the area must be put under protection and cultivation, and shall not be used for timber production. Lumbering shall be strictly banned.

**Cultivated land resources.** According to statistics, the six major administrative villages in Lugu Lake basin on the side of Sichuan Province now have cultivated lands of 9.21 square kilometers, of which lands with slope of 15-25 degrees account for 20% of the total and lands with slope of more than 25 degrees account for 24%. Total agricultural output value was 3.202 million Yuan in 2000, including 2.155 million Yuan from farm production. Farm production is the main source of income of local people. The cultivated lands in Lugu lake basin on the side of Yunnan Province

are 4.42 square kilometers, accounting for 8% of the total land in use. Most of lands in the Pingba area of Yongningba Prefecture are farmlands, and the area also has some paddy fields.

The cultivated lands in Lugu Lake valley area are in small proportion, and furthermore, some of them have been turned into forestlands due the big degrees of slopes. At the same time, some other cultivated lands are basically in conditions of planting a lot but yielding less because of the backward irrigation facilities and weak capability of fighting against natural disasters. From the angle of protecting of ecology and environment, and increase of income of local people, the lake area shall pursue adjustment of planting structure, and expansion of planting economic crops, especially economic trees in a bid to strengthen conservation of water and soil. For cultivated lands in good conditions, they shall be put into intensive cultivation to achieve the result of smaller quantity but better quality by taking such measures as accelerating construction of water conservancy and irrigation facilities, adding more organic fertilizer, recovering soil fertility, improving varieties of seed, and conducting intercropping and interplanting. The conclusion is that the utilization of cultivated land in Lugu Lake valley area shall be in keeping with the local conditions and combine planting trees with farm production, so as to increase economic efficiency, and also improve the general environment, thus making an effective use of the resources of cultivated lands. For Yongningba Prefecture, it can maintain the present scope of cultivated land, while shifting from the traditional farm production to development of modern ecological agriculture in a bid to increase economic efficiency.

**Grassland resources.** Currently, Lugu Lake valley area has natural grasslands of 2.9 square kilometers (of which about 1.3 square kilometers are on the side of Sichuan, and about 1.6 square kilometers on the side of Yunnan), accounting for about 1.5% of the land areas. The amount of livestock in the six major administrative villages on the side of Sichuan is 5,700-plus cattle and horses, 5,500-plus sheep, and 11,300-plus pigs;

and the amount on the Yunnan side is 1,500-plus cattle, horses and mules, and 4,000-plus pigs. The income of the animal husbandry in the area is 25% of the total output value of agriculture on the Sichuan part and 16% of the total on the Yunnan side. Raising of livestock such as cattle and horses in the area is mainly by regular herding, and that of pigs is in extensive breeding by putting them freely on the sides of the lake, leaving many animal excretion everywhere, which is not good to the environment. Some of the animals even gnawed the newly recovered grassland. The areas on the Sichuan have started breeding of domestic animals in captivity.

As the limited resources of grassland in Lugu Lake valley are mainly in areas of high elevation and slopes, they are not suitable for excessive herding of domestic animals for the purpose of not causing degeneration of grassland, and water and soil erosion. Grassland resources in scenic areas shall be put under an appropriate use and domestic animals shall be mainly raised in captivity, and they shall also promote grass planting and animal breeding technology, spread experience of crop-grass rotation, and use high-quality forage grass and fine breeds of animals so as to gain high economic returns. The adopting of breeding animals in captivity can also make effective utilization of excretion to produce methane, and fertilize farmland, thus improving the sanitary conditions of living for the local people.

**Aquatic resources.** Lugu Lake has rich resources of aquatic plants, boasting 37 types of 19 families, and forming more than 10 types of water plants communities. Of them, the *acuminata var crispa*, a waterweed, is a special product of the lake, which is edible for cold dish and soup. The waterweed area of the lake is about seven square kilometers, and local people use the waterweed as forage. The lake has four primitive species of fish and six secondary species. Of the primitive species, three types of schizothoracin fish are specially grown in the lake, known for their high value of nutrition, big body and tender and delicious meat. Before the introduction of fish species from the outside in the 1980s, the lake was abundant in schizothoracin fish, which can be easily caught by bare hands. A haul of the fish could reach more than

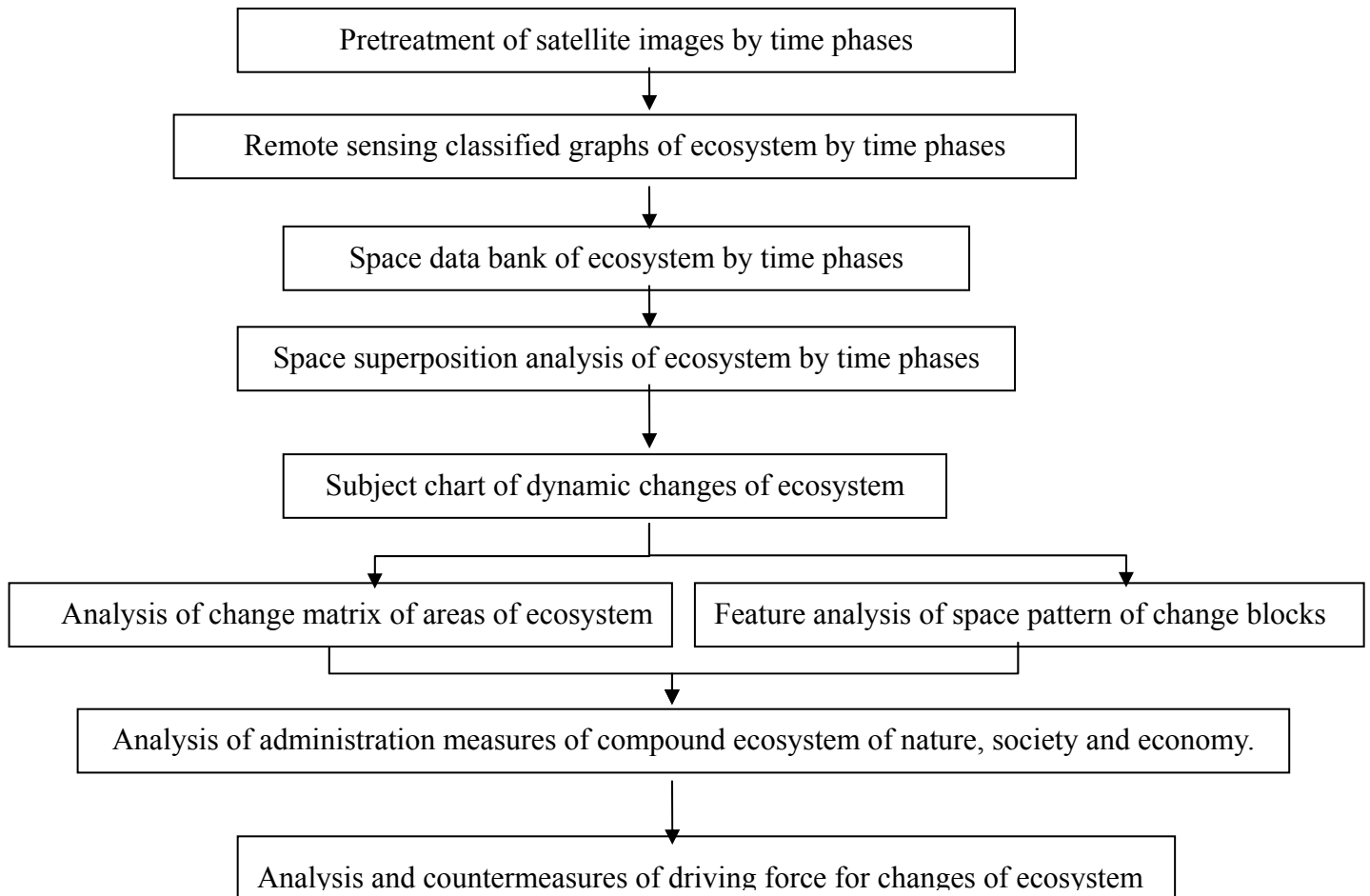
3,000 kilograms. The annual output of the fish was 300 tons. But the situation is much different now. The number of the schizothoracin fish has reduced sharply because fishes from the outside, which have eaten roes of the schizothoracin, and small-mesh net catching. The annual output of the fish was only two tons in the 1990s.

The aquatic resources of Lugu Lake are not only rich but also having its own characteristics, but the benefits of simple utilization for economic purpose is limited. Due to the lake filling up for increasing farmland, the waterweed area has shrunk, and the present excessive use of waterweed has shown sign of degeneration of the aquatic plants. What makes even worse is that the increasing numbers of boats operating on the waterweed area in the lake have forced migratory birds used to stay in the area in winter to move to Lianghai Lake. *Acuminata var crispa* are scattered at the lakebed of 1-5 meters deep. As Lugu is a deep-water lake, the plant has posed a sign of reduction because of water pollution of part of the lake water and excessive collecting. The primitive species of fishes in the lake are near extinction because of the introduction of fishes from the outside, and the excessive introduction of herbivorous fishes might also damage the water plants communities, harming the primitive ecological environment. At the same time, disordered and excessive breeding of fishes will also create pollution of the water system. At the present, Lugu Lake has been listed in the China's Plan on Protection of Biological Diversification. The protection and management of Lugu Lake are centered on ecology of the highland lakes to provide tight protection of terrestrial and water ecological environment and biological species. The lake shall make strict control in introduction of biological species from the outside, fix the time for closing the lake for protection, and make efforts to protect and recover the numbers of communities of water plants and the schizothoracin fish. So, the utilization of aquatic resources of Lugu Lake must be carried out under the preconditions of protecting ecological environment from further damage, and recovery of original plants.

### 3.3 Methodology

Research methods are mainly divided into three stages: satellite image treatment, gaining ecosystem information, and analyzing of changes of ecosystem (Fig. 1).

**Fig. 1 Flow process chart of research on changes in areas of ecosystem of Lugu Lake scenic areas**



Here would give more introduce to the process of following:

**Extracting information on ecosystem and constructing space data bank.** After treatment of the remote sensing graphs, we have gained information on types of ecosystem by way of classification. The types of ecosystem are made based on the principle of classification system in utilization of land. In accordance with the types of vegetation and characteristics of use of land in the Lugu Lake basin, we fix the classification of ecosystem of Lugu Lake basin (Table 2).

**Table 2 Classification of ecosystem of Lugu Lake basin**

Ecosystem Type	Distinguishing Marks for Remote Sensing Image Classification
Farmland	Irrigable Land, Paddy Field, Dry Land
Forest	Spruce-fir Forest, Lijiang Spruce Forest, Yunnan Pine Young Forest, Yunnan Pine Middle Growth Forest, Latifoliate Forest, Cold-wet Shrubbery, Economic Forest
Grassland	Alpine Meadow, Low Mountain Meadow, Abandoned Plough, Mud-rock Flow, Dry Riverbed
Water area	Lugu Lake, Other Lake, Reservoir, River and Swamp
Subsystem of Human Activity	Residential Area, Road, Stope, Commonland

The distinguishing marks for remote sensing image classification are made based on the 22 types of land utilization and biomes. According to the classification by rules of the Table1, the major ecosystems in Lugu Lake scenic areas are divided into four types, namely agricultural ecosystem, forest ecosystem, grassland ecosystem, and water ecosystem, and one subsystem of human activities, totaling five types.

**Analysis of changes of types of ecosystem.** Based on GIS platform, and through space superposition analysis of types of ecosystem in different times of period and simultaneous computation by analyzing the graphs before and after the changes, the attribute table of the new graphs consists of words of attributes ecosystem types before and after the changes. And then, using the SQL search language, we conduct the retrieval and analysis of space attributes.

### **3.4 Research results and analysis**

#### **3.4.1 Analysis of changing trend of areas of different types of ecosystem of Lugu Lake scenic areas.**

Table 3 shows the area value of the various types of ecosystem types of Lugu Lake scenic areas in four periods of time. From the table, areas of the four major nature ecosystems of farmland, forests, grassland, and water plants and animals have kept on changing in recent 15 years, presenting phased changes in degree.

**Table 3 Acreage transformation statistics of the various types of ecosystem types of Lugu Lake scenic areas**

System Types	1990	1995	2001	2005
Farmland Ecosystem(km <sup>2</sup> )	77.1	89.7	86.8	51.3
Forest Ecosystem (km <sup>2</sup> )	332.6	317.6	333.2	351.3
Grassland Ecosystem (km <sup>2</sup> )	24.3	24.2	26.6	37.4
Water Ecosystem (km <sup>2</sup> )	72.9	75.1	59.9	64.6
Human Activities Subsystem (km <sup>2</sup> )	2.7	2.9	3.0	5.0

**Note:** The classification of ecosystem types is based on the system principle of land use classification. Therefore, the classification system of Lugu Lake area is established in according with its different vegetation types and land use characteristic.

① **Farmland ecosystem:** It demonstrated an upward trend in the 1990-1995 period, increasing from 77.1 square kilometers to 89.7 square kilometers, posing an average annual increase of 0.495%; but in the 1995-2005 period, it appeared a downward trend year by year, during which, the annual decrease was 0.136% in 1995-2001, and the dropping rate changed to 1.682% in 2001-2005. This indicates that the work of recovering farmland into forestland starting in 2000 has helped speed up the reduction of farmland. In 2003, the areas of forestland recovered from farmland in Lugu Lake area was 1.27 square kilometers, increasing forest areas in the whole Lugu Lake areas by 0.6%, demonstrating a marked reduction of farmland.

② **Forest ecosystem:** It presented downward trend year by year in the 1990-1995 period, with annual decrease of 0.589%; and started a upward trend in the 1995–2005 period, in which, the forest area increased 0.523% each year in 1995-2001, and starting from 2001, the growth sped up to 0.867%. According to data analysis on



protection projects of natural forest resources of Ninglang County, the county stopped tree cutting of natural forests completely in 1999, completed man-made forests of 7.2 square kilometers, and artificial regeneration of natural forests of 118.5 square kilometers and close-up hillsides to livestock grazing and fuel gathering to facilitate afforestation covering an area of 184.57 square kilometers. All the efforts have added forestlands totaling 382.6 square kilometers, accounting for 10.1% of the original forest areas of 2,847.7 square kilometers. Protection of natural forests and recovering farmland into forestland has become the main sources for helping forest ecosystem grow strong.

③ **Grassland ecosystem:** It went downward turn year by year in the 1990-1995 period, with annual decrease of 0.002%, but started increasing year by year in the 1995-2005 period, in which, the annual growth in 1995-2001 was 0.089%, and starting from 2001, the growth sped up to 0.515%. The same is as the forest ecosystem. The protection of natural forests and recovering farmland into forestland and grassland were the main force in increasing the areas of grassland ecosystem.

④ **Water ecosystem:** It demonstrated upward turn year by year in the 1990-1995 period, with annual increase of 0.087%, but started downward trend in the 1995-2001 period, with annual decrease of 0.498%. The decrease was mainly attributed to watercourse renovation of the Kaiji River in Yongning Township starting from 1995, which reduced the water area of flood land sharply. But, starting from 2001, the water areas have maintained an average annual growth of 0.228% because of large amounts of waterweed piling up at the outlets of the wetland, which have helped raise the water level and increase the water area.

⑤ **Human activities subsystem:** One thing needs to be clear the human activities subsystem refers to the human activities in Lugu lake basin. It has kept on rising year by year in recent 15 years, and shown sign of speeding up the rises. In particular, the annual growth in the 2001-2005 period reached 0.094%. With the consistent

improvement of people's life and development of tourism industry, areas of newly-built roads and houses have made continuous increases in the area.

### 3.4.2 Comparison analysis of changes in areas of ecosystem in Lugu Lake scenic areas and the surrounding areas

The Table 4 shows the areas of various types of ecosystem of Lugu Lake scenic areas and the surrounding areas in four periods of time. The table indicates that the areas of the different types of the ecosystem in the surrounding areas of Lugu Lake have made the similar changes in recent 15 years. Areas of farmland and waters ecosystem have made continuous decreases, while areas of forest and grassland systems as well as human activities subsystem have increased.

Comparing the changing trends in the scenic areas, there are big differences between the two. From 1990 to 2005, the change rates of areas of farmland and waters ecosystems in the scenic areas stood at -33.5% and -11.4%, while that of the surrounding areas were -55.2% and -42.7%, respectively, indicating that the decreasing intensity of areas of farmland and waters in the scenic areas is weaker than that of the surrounding areas. But the increase of forest areas in the scenic area was 10.1% as against 5.6% in the surrounding areas; and the increase of grassland in the scenic areas was 53.9% as compared with 23.3% in the surrounding areas. Areas of human activities subsystem in the scenic areas increased 85.2%, and that of the surrounding areas went up 552.7%, posing a gap of 6.5 times between the two. From this point, the influence scope of human activities is comparatively steady in Lugu Lake areas.

**Table 4 Acreage transformation statistics of various types of ecosystem of surrounding areas of Lugu Lake scenic areas**

System types	1990	1995	2001	2005
Farmland Ecosystem(km <sup>2</sup> )	1072.2	749.1	977.4	480.5
Forest Ecosystem (km <sup>2</sup> )	6499.7	6879.8	6985.4	7153.6

Grassland Ecosystem (km <sup>2</sup> )	482.9	383.9	539.4	595.2
Water Ecosystem (km <sup>2</sup> )	718.5	766.0	170.0	411.6
Human Activities Subsystem (km <sup>2</sup> )	18.6	13.0	96.1	121.4

**Note:** This table lists four different periods' acreage of various ecosystem types in surrounding areas of Lugu Lake. We can see that the acreage of various ecosystem types changed continually in recent 15 years. The acreage of farmland and water ecosystem continually diminished, and that of forest and grassland ecosystem and human activity subsystem aggrandized.

### 3.4.3 Analysis of area changing matrix of ecosystems in Lugu Lake scenic areas in 1990-2005

By building the changing matrix of areas of ecosystems in the Lugu Lake scenic areas from 1990 to 2005 (Table 5), we have made further analysis of various transformation trends of major ecosystems in the areas. The analysis finds that the percentage of the part remained unchanged in the four major ecosystems of farmland, forests, grassland and waters in Lugu Lake scenic areas in recent 15 years are: 42.9%, 87.8%, 59.3% and 94.2%, respectively, thus comes to the ranking of steadiness of the major ecosystems in the areas are: waters, forests, grassland and farmland. At the same time, the human activities subsystem performed in a very unstable form, with changed areas accounting for 95.2% of the total.

**Table 5 Changing matrix of areas of ecosystems in Lugu Lake scenic area from 1990 to 2005**

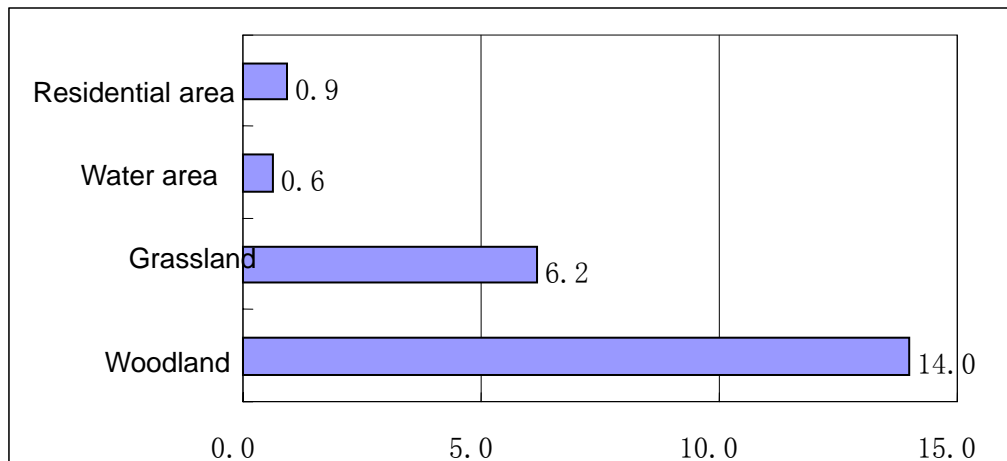
		2005				
		Farmland	Forest	Grassland	Water Area	Human Activity Subsystem
1	Ecosystem Types					
9	Farmland (km <sup>2</sup> )	21.67	3.88	1.71	0.17	0.26
0	Forest (km <sup>2</sup> )	18.61	320.12	11.11	2.04	0.48
	Grassland (km <sup>2</sup> )	9.58	37.18	18.92	1.21	0.42
	Water Area (km <sup>2</sup> )	0.15	2.91	0.03	55.48	0.04

	Human Activity Subsystem (km <sup>2</sup> )	0.48	0.65	0.13	0.00	0.06
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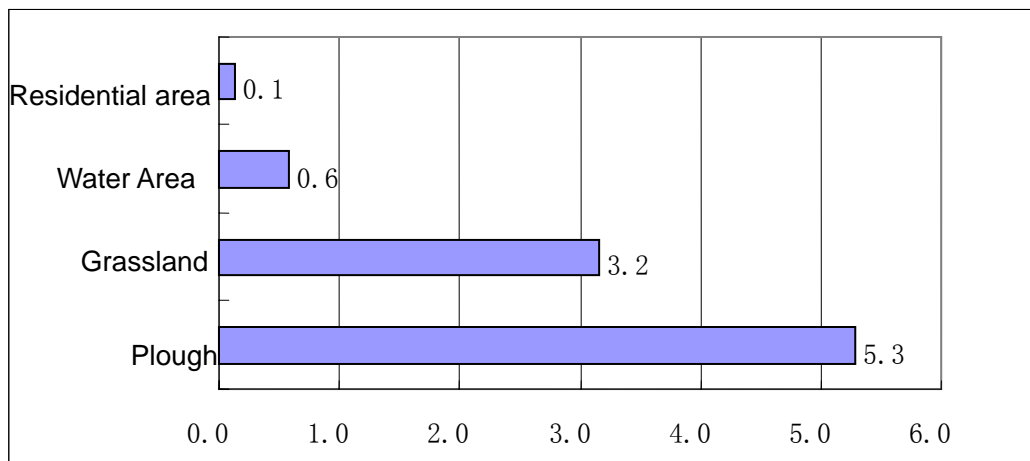
**Note:** During this 15-year, there are 5% of water ecosystem area transforming into woodland. These transformations, because of large-scale afforestation, mainly take place in original floodplain and swamp of river and lake. Investigation shows that walnuts were planted in most part of grass-ocean and swamp of Lugu Lake, Sichuan. These man-made transformations have many disadvantages. On one hand, because of high water table (average: 0.6m), unsuitable for growth of walnut, its economical benefit is hardly brought into play. On the other hand, the region was originally swamp ecosystem which has better function of ecosystem services, so man-made transformation into forest ecosystem will certainly decrease the function of the whole ecosystem.

Fig. 2, 3, 4 and 5 respectively show the direction and flow volume of inter-transition of the farmland, forest, grassland and waters ecosystem. The comparative Fig. 2, 3 and 4 show that the inter-transition between farmland and forestland takes up the main part of the changes in various types of ecosystems. Some 14% of farmland has been turned into forestlands, while only 5.3% of the forestlands were recovered into farmland, presenting a net increase of forestland by 8.7%. Meanwhile, the rate of farmland turning into grassland was 6.2%, while that of grassland turning into farmland was 14.2%, with increase of grassland areas by merely 8%. The transformation rate among other types has not exceeded 2%. The changes in the ecosystems in the areas are mainly taking place in the farmland, forestlands and grassland. Under such situation, how to deal with the contradiction between farmland and forestland, and between farmland and grassland is still a work of top priority in management of ecosystems in the areas. The principles of giving priority to protection of Lugu lake basin and maintaining the steadiness of the 95% of water areas and 88% of forest areas are the foundation to secure the steadiness of the overall ecosystems in the areas. Such proportion is 11% higher than the 77% of forestlands set by Ninglang County when it was constructing the shelter belt for the Yangtze River in 1992, showing that the local governments have attached great importance to the protection of the scenic areas of Lugu Lake.

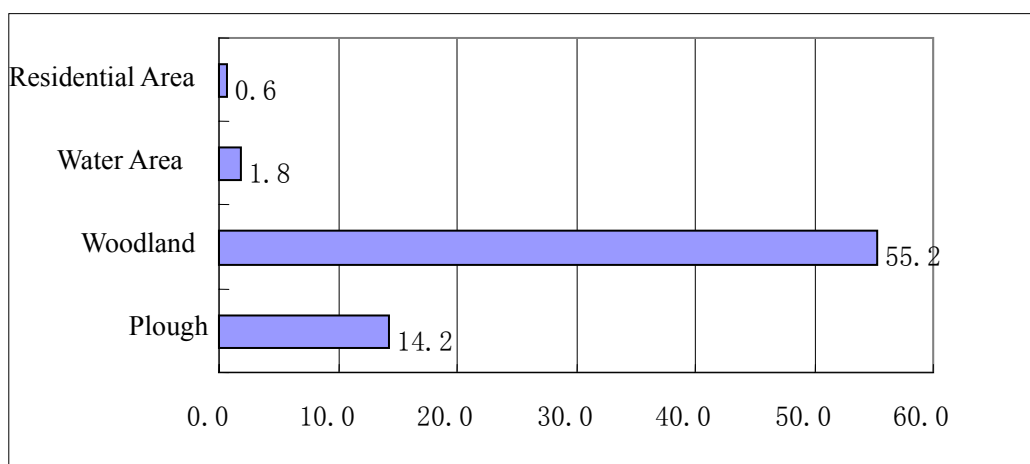
**Fig. 2 Flow volume proportion of farmland in 1990-2005 (%)**



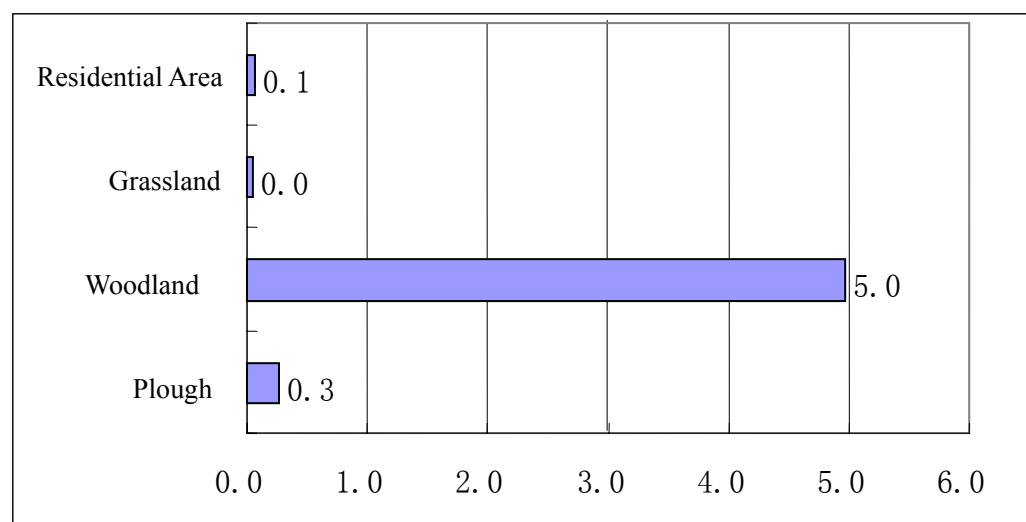
**Fig. 3 Flow volume proportion of woodland in 1990-2005 (%)**



**Fig. 4 Flow volume proportion of grassland in 1990-2005(%)**



**Fig.5 Flow volume proportion of water area in 1990-2005 (%)**



## 4. The economic valuation of Lugu Lake ecosystem services

### 4.1 Overview

About special eco-system or a certain ecosystem type in a certain area, there are many successful case of quantitative evaluation on its services. Although there are few evaluations on river basins, the integrated ecosystems can be divided into several different types of ecosystems to be analyzed. For the evaluation of Lugu Lake ecosystem services, we calculate the amount of substances at the first step, then calculate the value quantity based on price or project cost. The evaluation method means combination of material and value quantity.

The following Table 6 illuminates the calculation method on service value of Lugu Lake ecosystem. Combined with investigation data, we can quantitative calculate the basin ecosystem services.

**Table 6 Evaluation indices and methods of ecosystem services in Lugu Lake basin**

	Ecosystems' type Evaluation Index	Forest Ecosystem	Wetland Ecosystem	Thereinto: Lake	Agro Ecosystem	Grassland Ecosystem	Evaluation Method
Production Function	Product of Farming, Forestry, Animal Husbandry and Fishery	√	√	√	√	√	Market Value Method
Control Function	Climate Control	√	--	--	--	--	Shadow Price Method
	Absorb CO <sub>2</sub> (C accumulating)	√	√	--	√	√	Shadow Price Method
	Solid Conservation	√	--	--	--	√	Opportunity cost Method
	Environment Decontamination	√	√	--	--	√	Cost-Benefit Analysis Techniques

### The economic valuation of Lugu Lake ecosystem services

	Nutritional Circulation	√	--	--	--	√	Shadow Price Method
	Wind-breaking and Sand-fixing	√	--	--	--	√	Shadow Price Method
	Regulated Flow、Nurturing Water Source	√	√	--	--	√	Substitution Engineering Method
	Flood Control and Storage	--	√	√	--	--	Shadow Price Method
	Water Source Accumulation	--	√	√	--	--	Substitution Engineering Method
	Water Purification	--	√	√	--	--	Substitution Engineering Method
Support Function	Biodiversity	√	√	√	√	√	Opportunity Cost Method
	Release O <sub>2</sub>	√	--	--	√	--	Shadow Price Method
Culture Function	Cultural Diversity	√					Contingent Value Method
	Eco-tourism	√					Travel Cost Method
	Eco-aesthetics、Science Research	√					Contingent Value Method

**Note:** 1、“--”Show there are no corresponding service functions, or couldn’t be evaluated by now.

2、The cultural function is shown together by all ecosystem.

## 4.2. Production Supply

The productions’ supply function of ecosystems services mainly includes the productions of agriculture, forestry, livestock and fishery. For the area of Lugu Lake basin, ecosystem services mainly provide plant productions produced by agro ecosystem, fishery productions and domestic water supply produced by aquatic ecosystem, livestock productions produced by grassland ecosystem and timber productions and relative productions produced by forest ecosystem.

The total value of plant productions, fishery productions, livestock productions and



timber and relative productions is calculated through the local first industry income which presented in Table1,  $1148.9 \times 10^4$  Yuan. The determination of timber productions value was according to acreages of each type of forests and the stock volume of forest for each type of forests which based on the investigation. The overall value of timber productions is  $5336.4 \times 10^4$  Yuan which is calculated by 5% enhancement per year of standing volume of forest and multiplying per unit price of standing volume of forest 400 Yuan/  $m^3$ . For domestic water consumption, the total volume is  $47.7 \times 10^4 m^3$  per year, which is calculated by the total volume of local residents' water consumption adding to the overall water consumption of travelers. The total volume for local residents is the multiplying of the number of local residents, 13550 (In 2001, people in Luoshui Village was 2950, in Lugu county was 10600) and per capita water consumption 60L/d. For travelers' water consumption, it is calculated by the number of travelers which is based on the data of year 2004, 409 thousands/y and 2 days as staying and visiting period in Lugu basin area, and per capita water usage, 220L (the average per capita water consumption in city area in China). The total value of domestic water supply is 477 thousand/y, based on the per unit water price is 1Yuan/ $m^3$ .

Therefore, the overall value of ecosystems' productions supply function is 65330 thousands Yuan in Lugu Lake basin area.

**Table 7 Type of forests and stock volume of forest in Lugu Lake basin**

Types of Forests	Shrubs	Economic Forest	Latifoliate Forest	Lijiang Spruce forest	Spruce-fir forest	Yunnan Pine Young Forest	Yunnan Pine Middle Growth Forest
Acreage ( $hm^2$ )	2921.3	456.9	3533.8	3225.1	243.9	1651.7	714.3
Per unit Stock volume of forest ( $m^3/hm^2$ )	70	70	331	240	400	150	200
Stock volume of forest ( $m^3$ )	20.4	3.2	117.0	77.4	9.8	24.8	14.3

**Source:** The total value of plant productions, fishery productions, livestock productions and timber and relative productions is calculated through the local first industry income which presented in Table1

### 4. 3 Regulation function

Regulation functions mainly including: climate regulation、Erosion control and soil retention, conservation of water resource, wind prevention and sand fixation, soil melioration, pollution alleviation and so on. These functions of ecosystems services are significant to the improvement of eco-environment and maintenance of the ecological balance.

#### 4.3.1 Soil conservation

According to universal soil loss equation (USLE) to count:

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

Where, A: Average annual erosion in field sized area ( $t/hm^2 \cdot a$ );

R: Rainfall-runoff (erosivity) factor ( $Ft.T.In/A.h$ );

K: Soil erodibility factor;

LS: Topographic factors (L represent slop length, S represent slop gradient)

C: Crop type factor;

P: Soil conservation practice factor

As for potential soil erosion factor ( $A_p$ ) , the cover and management factor and soil conservation practice factor do not need to be considered in the calculations, so  $C=1$ ,  $P=1$ ,

Therefore:

$$A_p = R \cdot K \cdot LS$$

As actual soil erosion factor ( $A_r$ ) , the crop type factor and soil conservation practice factor should be considered in the count,

Therefore:

$$A_r = R \cdot K \cdot LS \cdot C \cdot P$$

The Volume of soil conservation is:  $A_c = A_p - A_r$

#### ① Determination for R

Equation provided by Fujina Zhou Yan Huang et al (Fujian Zhou et al, 1995), which is based on the experimental data in southern China, to determine the value of R was used in this paper. The monthly precipitation was considered in this equation. This equation is adaptive to geographical environment in Southern China.

$$R = \sum_{i=1}^{12} (-1.5527 + 0.1792P_i)$$

Where,  $R$ : Rainfall-runoff (erosivity) factor (Ft.T.In/A.h)

$P_i$ : Monthly precipitation (mm)

Based on the statistical data of monthly precipitation in Lugu Lake basin between the year 1971 and 2004 from the Weather Bureau of Ninglang county, the average monthly precipitation was calculated. Using previous equation, the value of R was 149.69.

## ② Determination for K

The characteristics and the proportion of organic matter were acquired through the materials of soil investigation, and then found the value of K from Nomogram which was set up by Wischmeier et al, US.

**Table 8 The value of soil erodibility factor (K) in USLE**

Characteristics of Soil	Proportion of organic matter (%)			Characteristics of Soil	Proportion of organic matter (%)		
	0.5	2	4		0.5	2	4
Sand	0.11	0.07	0.04	Loam	0.85	0.76	0.65
Fine Sand	0.36	0.31	0.22	Silt loam	1.08	0.94	0.74
Extreme fine sand	0.94	0.81	0.63	Silt	1.34	1.16	0.94
Loamy Sand	0.27	0.22	0.18	Sandy Clay Loam	0.60	0.56	0.47
Loamy Fine Sand	0.54	0.45	0.36	Clay Loam	0.63	0.56	0.47
Loamy Extreme Fine	0.99	0.85	0.67	Silty Clay Loam	0.83	0.72	0.58

Sand							
Sandy Loam	0.60	0.54	0.43	Sand Clay	0.31	0.29	0.27
Fine Sandy Loam	0.78	0.67	0.54	Silty Clay	0.56	0.52	0.43
Extreme Fine Sandy Loam	1.05	0.92	0.74	Clay	0.65	0.47	0.29

**Note:** The characteristics and the proportion of organic matter were acquired through the materials of soil investigation, and then found the value of K from Nomogram which was set up by Wischmeier et al, Wischmeier (1969) measured soil erodibility index in simulated rainfall experiment;

### ③ Determination for LS

Based on the equation set up by Fujian Zhou Yanhe Huang et al, the dimensional distribution characteristics of LS can be obtained.

$$LS=0.08\lambda^{0.35}\alpha^{0.6}$$

Where,  $\lambda$ : Slope Length (m);

$\alpha$ : Percentage Slope

### ④ Determination for C

Crop type factor is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss, which is related to the land use pattern and coverage density closely. Using the different vegetation pattern from investigation and relative average coverage density to find the value of C of different patterns of vegetation is found from the Table of Value C in USLE (Wanzhong Wang et al, 1996).

**Table 9 The value of C of different patterns of vegetation in USLE**

Ration of coverage (%)	0	20	40	60	80	100
Meadow	0.45	0.24	0.15	0.09	0.043	0.011
Shrubs	0.40	0.22	0.14	0.085	0.040	0.011
Mixed Arbor and Shrub	0.39	0.20	0.11	0.06	0.027	0.007
Flourish Forest	0.10	0.08	0.06	0.02	0.004	0.001

**Source:** Wanzhong Wang, Juying Jiao 1996, Quantitive evaluation research on China's soil erodibility factor, Journal of Water and Soil Conservation, 16(5): 1-20.

### ⑤ Determination for P

The P value is 0.15 in paddy field. Other land use patterns do not be implemented in any methods for soil conservation, so the value should be 1.00.

**Table 10 The calculation results of amount of soil conservation in Lugu Lake**

Biomes	Sub-biomes	Acreage * (hm <sup>2</sup> )	Amount of soil conservation (t)	Amount of soil per unit area (t/ hm <sup>2</sup> )
Meadow Land	Meadow land	869.4	22302	25.7
Farmland	Dry Land	903.8	13869	15.3
Farmland	Paddy Field	52.0	639	12.3
Forest	Shurbs	2921.3	96945	33.2
Forest	Economic Forest	456.9	6572	14.4
Forest	Broad Leaf Forest	3533.8	106886	30.2
Forest	Lijiang Spruce Forest	3225.1	65456	20.3
Forest	Spruce-fir Forest	243.9	5779	23.7
Forest	Yunnan Pine Young Forest	1651.7	35032	21.2
Forest	Yunnan Pine Middle Growth Forest	714.3	16555	23.2
Total		14572.3	370036	25.4

**Note:**\* Based on USLE, the amount of soil erosion can not be calculate when the value of slope is zero, so the total acreages in the table do not include the acreage with zero slope.

Based on the investigation, the depth of surface soil is 0.36m in farmland (dry land) in Lugu Lake basin and soil density is 1.44t/m<sup>3</sup>. The amount of soil conservation

converting into the acreages of farmland is  $71.4\text{hm}^2$ . Local per unit of acreage (Mu) crop yield is 200 kilograms and per unit price is 1.6 Yuan (average price in 2004 in China), so the value of the soil conservation is  $34.3 \times 10^4$  Yuan/a in Lugu Lake basin.

#### 4.3.2 Conservation of water resource

This study used the water storage effect of forest ecosystem to measure the amount of water conservation in forest ecosystem, namely, method of rainwater containment.

$$Q = A \cdot J \cdot R / 1000$$

Where:

Q: The amount of increasing water conservation in forest ecosystem, compared to the quantity of bare land ( $10^4\text{t}$ );

A: The acreage of study area ( $\text{hm}^2$ );

J: Average annual precipitation which produce runoff in study area (the precipitation at one time is  $>20\text{mm}$ );

R: The effect index of water conservation in forest ecosystem, compared to bare land.

Based on the materials supplied by weather bureau of Ninglang county, the amount of average annual precipitation (1971-2004) in Lugu Lake Basin was 939.3mm, and the amount of precipitation which produced runoff was 318.9mm.

Determination for R: Subtropical evergreen broad-leaved forest 0.39;

Subtropical evergreen coniferous forest 0.36;

Subtropical evergreen-deciduous broad-leaved mixed forest 0.34

Alpine meadow 0.25

Wetland 0.40

The value of water conservation in each type ecosystem in Lugu lake basin was showed in Table 11. The value of water conservation was calculated by replacement cost technique, namely, evaluation through reservoir construction cost ( $0.67\text{Yuan} \cdot \text{m}^{-3}$ ,

at 1990s' constant price). The evaluation results of value of water conservation in Lugu lake basin were showed in Table 11.

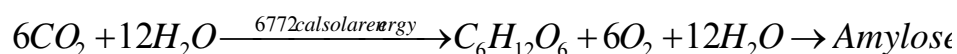
**Table 11 Calculation results of water conservation in Lugu Lake basin**

Biomes	Sub-biomes	Acreage ( $\text{hm}^2$ )	R	Amount of water conservation ( $10^4\text{t/a}$ )	Value ( $10^4\text{Yuan/a}$ )
Meadow ecosystem	Meadow	1296.1	0.25	103.3	69.2
Forest ecosystem	shrub	4001.9	0.34	433.9	290.7
Forest ecosystem	Economic Forest	838.2	0.34	90.9	60.9
Forest ecosystem	Broad-leaved Forest	4369.8	0.39	543.5	364.1
Forest ecosystem	Lijiang Spruce Forest	4129.5	0.36	474.1	317.6
Forest ecosystem	Yanna Fir Forest	255.9	0.36	29.4	19.7
Forest ecosystem	Yong aged Yunnan Pine Forest	2018	0.36	231.7	155.2
Forest ecosystem	Middle aged Yunna Pine Forest	896.5	0.36	102.9	68.9
Aquatic system	Wetlands	459.5	0.40	58.6	39.3
Total		25288.9	-	2068.3	1385.8

**Note:** R from Tongqian Zhao The research of terrestrial ecosystem services function and its value evaluation Thesis for applying doctor's degree in graduate school China Academy of Sciences

### 4.3.3 CO<sub>2</sub> absorption

Based on data of primary production on different types of forest from other researches, for forest, the amount of CO<sub>2</sub> absorption and O<sub>2</sub> release was calculated by following equation, namely, 1gram dry vegetation dry matter needs 1.63grams CO<sub>2</sub> to produce 1.2gramsO<sub>2</sub>



Determination for primary production:

West evergreen broad-leaved forest:  $16.28 \text{ t} \cdot \text{hm}^{-2} \cdot \text{a}^{-1}$

Evergreen evergreen-deciduous broad-leaved mixed forest:  $4.5 \text{ t} \cdot \text{hm}^{-2} \cdot \text{a}^{-1}$

Yunna pine forest  $9.31 \text{ t} \cdot \text{hm}^{-2} \cdot \text{a}^{-1}$

Yun spruce forest:  $8.13 \text{ t} \cdot \text{hm}^{-2} \cdot \text{a}^{-1}$

Lijiang fir forest:  $8.61 \text{ t} \cdot \text{hm}^{-2} \cdot \text{a}^{-1}$

**Table 12 The quantity and value of CO<sub>2</sub> absorption of forest ecosystem in Lugu Lake basin**

Biomes	Sub-biomes	Acreage (hm <sup>2</sup> )	Net Primary Production (t·hm <sup>-2</sup> ·a <sup>-1</sup> )	Quantity (t·a <sup>-1</sup> )	CO <sub>2</sub> Absorption (t·a <sup>-1</sup> )	Value (Afforestation Cost Method) (10 <sup>4</sup> Yuan·a <sup>-1</sup> )
Forest	Shrubs	4001.9	4.5	18008.6	29353.9	209.0
Forest	Economic Forest	838.2	4.5	3771.9	6148.2	43.8
Forest	Broad-leav ed Forest	4369.8	16.28	71140.3	115958.8	825.6
Forest	Lijiang Spruce Forest	4129.5	8.61	35555.0	57954.6	412.6
Forest	Yunnan Fir Forest	255.9	8.13	2080.5	3391.2	24.1
Forest	Young aged Yunnan Pine Forest	2018	9.31	18787.6	30623.8	218.0
Forest	Middle aged Yunnna Pine Forest	896.5	9.31	8346.4	13604.7	96.9
Total		25288.9	-	157690.3	257035.1	1830.1

**Note:** Using China's forestation cost, 260.90Yan/tC (at 1990s' current price) to calculate, the value of CO<sub>2</sub> absorption was 71.2Yan/ tCO<sub>2</sub>

#### 4.3.4 Making the environment clean

##### ① SO<sub>2</sub> holding and dust detention by forests

According to monitoring, when sulfur dioxide going through a plane tree belt of 15



meters high and 15 meters wide, it can help reduce the density by 25-75% ( Li Jinchang, etc, 1999). Generally speaking, the adherent capacity of broadleaf trees is 88.65 kg/hm<sup>2</sup>; cypress trees 411.60 kg/hm<sup>2</sup>; fir trees, 117.60 kg/hm<sup>2</sup>; and pine trees, averaging 215.60 kg/hm<sup>2</sup> (Ouyang Zhiyun, etc, 1996).

A research shows that a hectare of pine trees can adhere 36.0t of dusts each year; that of fir trees, 30.0t; and that of oak trees, 67.5t. A city with sound afforestation conditions has only 1/9 – 1/8 dust fall than a city in deficiency of trees. Commonly, coniferous tree forests have the dust detention capacity of 33.20 t/hm<sup>2</sup> a year, and broadleaf tree forests, 10.11 t/hm<sup>2</sup> (Ouyang Zhiyun, etc, 1996).

**Table 13 Underlying SO<sub>2</sub> holding and dust detention capacity of Lugu Lake basin forest ecosystem**

Biomes	Sub-biomes	Acreage (hm <sup>2</sup> )	SO <sub>2</sub> Absorption Ability (kg.hm <sup>-2</sup> .a <sup>-1</sup> )	Dust Detention Ability (kg.hm <sup>-2</sup> .a <sup>-1</sup> )	SO <sub>2</sub> Absorption (t..a <sup>-1</sup> )	Dust Detention Capacity (t..a <sup>-1</sup> )
Forest	Shrubbery	4001.9	88.65	67.5	354.8	270.1
Forest	Economic Forest	838.2	88.65	10.11	74.3	8.5
Forest	Latifoliate Forest	4369.8	88.65	10.11	387.4	44.2
Forest	Lijiang Spruce Forest	4129.5	117.60	30.0	485.6	123.9
Forest	Spruce-fir Forest	255.9	117.60	30.0	30.1	7.7
Forest	Yunnan Pine Young Forest	2018	117.60	36.0	237.3	72.6
Forest	Yunnan Pine Middle Growth Forest	896.5	117.60	36.0	105.4	32.3
Total		25288.9	-	-	1674.9	559.3

**Source:** Ouyang Z Y, Wang R S, 1996. Indirect Value Assessment of China Biodiversity [M]. Beijing: China Science and Technology Press. 409-421.

The potential SO<sub>2</sub> holding and dust detention capacity of the forests ecosystem in Lugu Lake valley is 1674.9t/a and 559.3t/a, respectively. Based on the cost of 600

Yuan·t<sup>-1</sup>·a<sup>-1</sup> for investment and disposal of sulfur dioxide and the cost of 170 Yuan·t<sup>-1</sup>·a<sup>-1</sup> for operation of dust removing, the value of the potential SO<sub>2</sub> holding and dust detention capacity of Lugu Lake forests ecosystem is estimated at 100.5 × 10<sup>4</sup> Yuan/a and 9.5 × 10<sup>4</sup> Yuan/a, respectively.

## ② Degradation of obsolescence on grassland

In the process of animal herding, large amounts of excretion are left allover the grasslands, which will be degraded under the joint roles of weathering, drenching, biological fragmenting and microbial decomposition, and their nutrients return to the grasslands. Such function avoids large amounts of animal excretion from storing up, playing an important role in maintaining the function and performance of the grassland ecosystem.

The evaluation of the degrading capability and nutrient returning function of animal excretion in the grassland ecosystem is made through estimation of aggregate nutrients in sample part of grasslands and animal excretion on the grasslands of Lugu Lake areas. The following is the formula we used in the physical quantitative evaluation:

$$G = \lambda \sum_{i=1}^2 \sum_{j=1}^3 W_i \cdot r_{ij} \cdot \omega_{ij}$$

In the formula, G refers to the aggregate returned nutrient matters from the degradation of the obsolescence,  $\lambda$  refers to the proportion of animal excreta returning to the grassland, i, j refer to types of livestock (cattle, horse and sheep) and types of nutrients (N、P<sub>2</sub>O<sub>5</sub>) respectively, W<sub>i</sub> refers to the different carrying capacity of cattle, horse and sheep collected from the grassland, r<sub>ij</sub> refers to the quantities of excreta of different types of livestock, and  $\omega_{ij}$  refers to the average contents of nutrient elements of excreta of different types of livestock.

By using the shadow price method in magnitude of value, we has made evaluation of ecological economic value of the degradation of obsolescence matters and nutrient

returning function in the grassland ecosystem based on the average price of chemical fertilizer in China. According to a test (Zeng Zhengdong, etc, 1996), the average daily excreta of each cow is 25kg, with the proportion of excrement and urine standing at 3:2. The excreta of sheep are 0.53 – 0.71 kg in dry volume  $\cdot d^{-1}$  (Wang Shiping, etc, 2000). According to a research conducted by Jiang Lihong (1997) in cooperation with others in Ewenki Autonomous Banner in North China's Inner Mongolia, based on the calculation of dry matter volume, the organic content of cow excrement is 88.3%, the N content, 1.5%, and  $P_2O_5$  0.7%. The organic content of sheep pen excrement is 90.8%, the N content, 2.4%, and  $P_2O_5$  0.7%. The organic content of horse stable is 87.6%, the N content, 2.0%, and  $P_2O_5$  0.9%. Based on such calculation, each cow and horse empties N36.6kg, and  $P_2O_5$  12.8kg each year, and each sheep, N6.2kg and  $P_2O_5$  2.8kg.

According to a survey, the total number of cattle and horses in various villages in Lugu Lake areas was 24,211 heads in 2001, and that of sheep was 6,392. Supposing that the returning rate of animal excreta to the grassland is 0.4%, the physical volume of obsolescence degradation and nutrient returning function in the grassland ecosystem in Lugu lake basin shall be N 370.3 tons, and  $P_2O_5$  131.1 tons. Based on the average price of chemical fertilizer in China of 2,549 Yuan  $\cdot t^{-1}$  (Drafting group of the Research Report on Biological Diversification in China, 1997), the value of obsolescence degradation and nutrient returning function in the grassland ecosystem is  $127.8 \times 10^4$  Yuan/a.

### ③ Purification of lake water

Lake has the capability of self-purification to remove various pollutants in the water. Currently, we can hardly make any evaluation on the pollutant removing function and efficiency as there have been no sufficient systematic studies on the subject. Our research tries to reflect purifying function and value of water systems by conducting research on the removing efficacy of nitrogen (N) and phosphorus (P) of lakes. With reference to the per unit N and P removing function of the Erhai Lake and Qionghai Lake (Table 14), the potential N and P purifying capability of Lugu Lake is estimated

at N105.3t/a, p22.55t/a, and the N and P purifying capacity of Lakes can be evaluated in accordance with the disposal cost of household sewage of N1.5 Yuan·kg<sup>-1</sup> and P 2.5 Yuan·kg<sup>-1</sup>. The evaluation result is that the efficiency of N and P purifying capability of Lugu Lake is 21.4 x 10<sup>4</sup> Yuan /a.

**Table 14 N&P's cleaning by Erhai Lake and Qionghai Lake in Yunnan-Kweichow Plateau**

Lake Name	Acreage (km <sup>2</sup> )	Cleaning N (t.a <sup>-1</sup> )	Cleaning P (t.a <sup>-1</sup> )	N's Cleaning Ability (t.km <sup>-2</sup> .a <sup>-1</sup> )	P's Cleaning Ability (t.km <sup>-2</sup> .a <sup>-1</sup> )
Erhai	250	678.6	90.3	2.7	0.4
Qionghai	31	103.21	15.56	3.3	0.5

**Notes:** The data is obtained from project“*Studies on Sustainable development of Lugu Lake Basin*”.

#### 4.3.5 Cycle of nutrient matters

According different N, P, K contents of forest-type plants (Table 15) and net primary productivity, the holding volume of such N, P, K nutrients can be reckoned up.

**Table 15 Plant body nutriment content**

Categories	Sub-categories	Acreage (hm <sup>2</sup> )	Net Elementary Productivity (t.hm <sup>-2</sup> .a <sup>-1</sup> )	Plant Body Nutriment Content			
				N %	P %	K %	P <sub>2</sub> O <sub>5</sub> %
Forest	Shrubbery	4001.9	4.5	0.456	0.032	0.221	0.073
Forest	Economic Forest	838.2	4.5	0.456	0.032	0.221	0.073
Forest	Latifoliate Forest	4369.8	16.28	0.531	0.042	0.201	0.096
Forest	Lijiang Spruce Forest	4129.5	8.61	0.33	0.036	0.231	0.082
Forest	Spruce-fir Forest	255.9	8.13	0.33	0.036	0.231	0.082
Forest	Yunnan Pine Young Forest	2018	9.31	0.400	0.085	0.227	0.195
Forest	Yunnan Pine Middle Growth Forest	896.5	9.31	0.400	0.085	0.227	0.195
Total			-				

**Source:** Zhao Tongqian. The Research of Terrestrial Ecosystem services Function

and Its Value Evaluation. Thesis for Applying Doctor's Degree in Graduate School China Academy of Sciences

Through computation, the cyclic volume of nutrient matters of the forest ecosystem of Lugu Lake areas is estimated at N 709.8t/a、P<sub>2</sub>O<sub>5</sub>168.0t/a, K339.7t/a. By adopting the shadow price method, and estimating the average price of chemical fertilizer in China standing at 2,549 Yuan/t, the value of nutrient matters of the forest ecosystem of Lugu Lake areas is  $310.3 \times 10^4$  Yuan/a.

#### **4.3.6 Water volume regulation and storage**

##### **① Flood regulating**

Lugu Lake's water area for an average year is 50.1 square kilometers, and annual changing range of water level is 0.7-0.1m, and the amount of dynamic reserve is  $0.351-0.50 \times 10^8 \text{m}^3$ , averaging  $0.426 \times 10^8 \text{m}^3$ .

The marshland area of the lake area is 5.9 square kilometers. Reckoning the highest inundating depth of 1.0 meters in the flood period, the flood storage capacity is  $0.059 \times 10^4 \text{m}^3$ .

##### **② Storage of water resources**

Total water storage of Lugu Lake (including the water storage of the marshland), is  $22.52 \times 10^8 \text{m}^3$ .

By using the substitute engineering method to reckon up the value of the water regulating and storage function of Lugu Lake, the total value is  $15.4 \times 10^8 \text{Yuan} \cdot \text{a}^{-1}$  by taking the cost of reservoir water storage as  $0.67 \text{Yuan} \cdot \text{m}^{-3}$ .

#### **4.4 Supporting function**

Supporting function is an essential basic function for ensuring other ecosystems to provide their service functions. As it is different from the supply, and regulating functions of a product and cultural service, the supporting function exerts indirect

impact on the human being, or impact which may take place after a long period of time, while the service of other types is comparative directly and short term. For example, people do not achieve services by making use of soil, but the soil transformation will exert influence on human being by affecting food production and providing service. Equally, the function of oxygen production by the photosynthesis role shall belong to the supporting function, mainly because that the impact on oxygen density in the air will only pay off through a very long period of time. Others which belong to the supporting function include fixing of solar energy, primary production, nitrogen cycle, water cycle and ecological environment.

#### **4.4.1 O<sub>2</sub> releasing**

According to the types of trees, using the O<sub>2</sub> volume by computation and assimilation of net primary productivity to reckon up the O<sub>2</sub> releasing volume of Lugu Lake forest ecosystem, the result is shown in the Table 16.

**Table 16 O<sub>2</sub> release of forest ecosystem in Lugu Lake basin**

Biomes	Sub-biomes	Acreage (hm <sup>2</sup> )	R	Amount of water conservation (10 <sup>4</sup> t/a)	Value (10 <sup>4</sup> Yuan/a)
Meadow ecosystem	Meadow	1296.1	0.25	103.3	69.2
Forest ecosystem	shrub	4001.9	0.34	433.9	290.7
Forest ecosystem	Economic Forest	838.2	0.34	90.9	60.9
Forest ecosystem	Broad- leaved Forest	4369.8	0.39	543.5	364.1

**Note:** By adopting the shadow price method and according to the cost of 352.93 Yuan (at constant price of 1990) on afforestation in China, the reckoned value is 6,678.4 x 10<sup>4</sup> Yuan.

#### **4.4.2 Maintaining biological diversification**

It is of great importance to maintain the biological diversification of Lugu Lake areas, forests and marshlands. The value of the function is calculated by areas in combination of the result of the research on the value of maintaining the biological diversification of forests and marshlands in China made by Zhao Tongqian (2004).

According to the research result of Zhao, the total value of the function of maintaining the biological diversification of ecosystem in nature reserves of the national forest ecosystem is  $495.94 \times 10^8$  Yuan·a<sup>-1</sup>. The service function of marshlands in the country in providing habitats or “asylum” for birds and animals creates ecological efficiency amounting to  $341.5 \times 10^8$  Yuan·a<sup>-1</sup> each year. China’s area of nature reserves of forest ecosystem is  $3028.95 \times 10^4$  hm<sup>2</sup>, and that of marshlands, 93,972.7 km<sup>2</sup>.

According to the areas of  $2.53 \times 10^4$  hm<sup>2</sup> of the nature reserves of the forest ecosystem of Lugu Lake and that of 5.9 km<sup>2</sup> of marshlands, the aggregate value in the areas is estimated at  $4,356 \times 10^4$  Yuan by maintaining the biological diversification.

#### **4.5 Cultural tourism function**

The cultural tourism function refers to non-material benefits gained by people from ecosystem through moral feeling, knowledge learning, objective impression, entertainment and recreation and aesthetic experience, which mainly include diversified national culture, moral and religious value, social relations, knowledge system (traditional and tangible ones), education value, inspiration, aesthetic value and value of cultural heritage, which have their distinctive features and formed and developed on the basis of the forest ecosystem. The cultural tourism value of Lugu Lake areas can be divided into two of tourism value and cultural value.

The tourism value mainly concentrated on the income from tourist admission tickets. Lugu lake basin received a total of 409,000 tourists in 2004, with ticket income hitting 7.50 million Yuan. According to the Outline of the General Plan of Scenic Spots in

Lugu Lake areas drafted by the China Urban Planning and Designing Institute entrusted jointly by the Government of the Yi Autonomous County of Ninglang and the YanYuan County Government, the ideal tourist scale of Lugu Lake areas is estimated at 600,000 persons a year. According to the number of tourist admission tickets sold and the number of tourists they received in 2004, the potential admission ticket income of the areas may reach 11 million Yuan.

It is difficult to evaluate the cultural value by using the market value. Our research makes indirect evaluation of the cultural value by using the method of payment intention. According to a questionnaires survey, the intended payment of tourists for protection of the local Mosuo traditional culture is 22 Yuan/person/time. Based on such payment intention and the ideal scale of tourists of 600,000 a year, the cultural value of the ecosystem services of Lugu Lake areas is estimated at 13.20 million Yuan/year. So, the total value of both the cultural and tourism functions of the ecosystems of the areas shall be 24.20 million Yuan/year.

#### **4.6 Analysis of findings of the questionnaire survey on tourism value of Lugu Lake by tourists**

Among the 70 effective questionnaires papers from tourists, in response to the question of what attract tourists most in Lugu Lake scenic areas, 80% ticked natural scenery, 70% for local folkways, 20% for religious culture, and 3% held that the history of Mosuo people is the main aspect in attracting tourists.

For selection of the most attractive things for tourists in Lugu Lake areas, 47% of the tourists chose natural scenery, 20% selected local folkways and religious culture, and 33% ticked several items of natural scenery, local folkways and religious culture. This indicates that it is very important to protect the ecological environment in the process of development of tourism in the scenic areas of Lugu Lake.

As development of tourism may exert impact on local traditions and folkways, 84% of



the survey tourists held that it is necessary to take measures to protect the traditional culture of the Mosuo people, only 11% said not necessary, and 5% gave no answers.

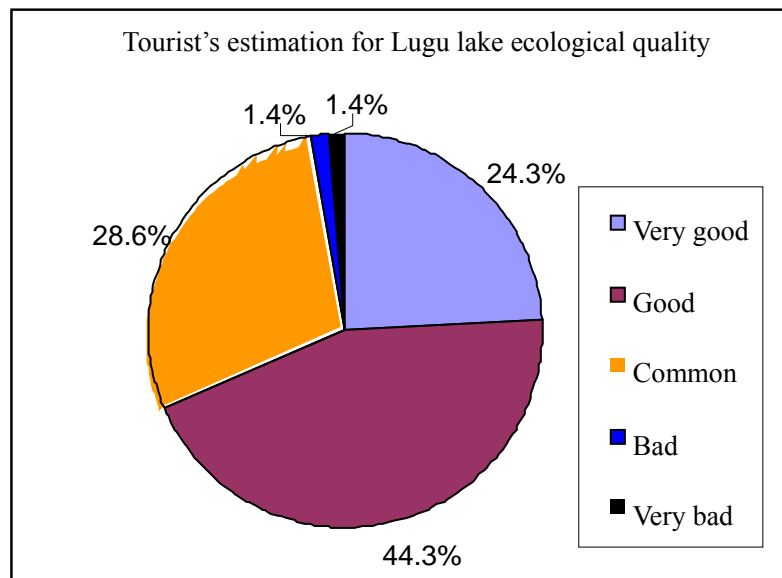
Some 86% of the tourists said that the areas should restrict the numbers of tourists in a bid to provide better protection of the ecological environment of Lugu Lake scenic areas. Among those selecting restricting the number of tourists, 70% held that the areas shall set maximum limit for number of tourists each day. In addition, 6% suggested hikes of prices of admission tickets, and 11% of them gave unclear answers or kept the column blank.

Development of tourism may bring about influence on the ecological environment of Lugu Lake. 83% of the survey tourists held that deterioration of the lake 's ecological environment would bring about big and very big impact on the tourism value of the lake, only 16% said that there would be small or no impact, and 4% gave no answers. But among tourists who said the deterioration of ecological environment would have little or no impact on the tourism value of the lake, most of them held that the main reasons attracting tourists to Lugu Lake are the local tradition and religious culture.

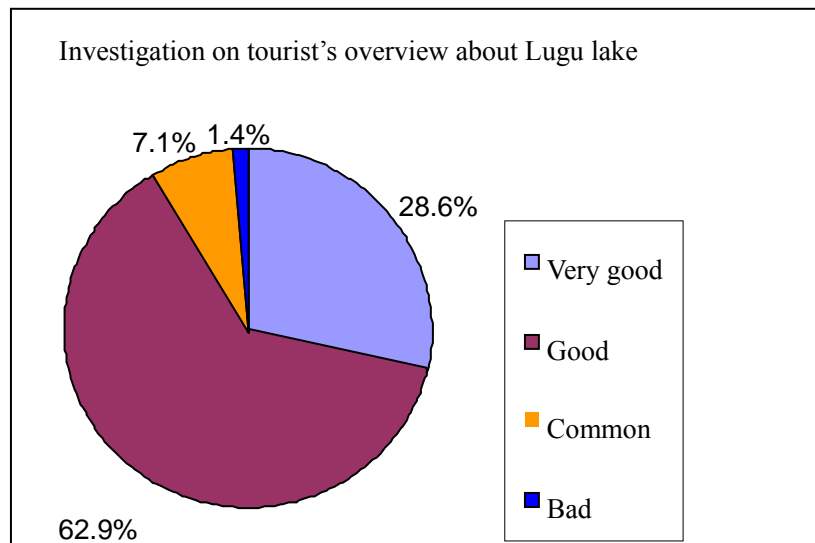
Fig 6 shows the statistics of findings of quality evaluation of ecological environment in Lugu Lake scenic areas by tourists. Among them, 68.6% said good or very good; 28.6% said so-so; and 2.8% commented poor or very poor, which indicate that tourists are generally satisfied with the present quality of the ecological environment of Lugu Lake areas.

Fig 7 shows the findings of the general impression from traveling in Lugu Lake, which shows that the tourists are also satisfactory with their tour. As Lugu Lake is the habitats of many rare and precious animals, the areas have set up nature reserves to protect them. In reply to the question that is it necessary to enhance propaganda and management measures on protection of the rare and precious animals and plants, 87% of the surveyed said "necessary, 9% said "not necessary, and 4% gave no answers.

**Fig. 6 Tourist's estimation for Lugu Lake ecological quality**



**Fig. 7 Investigation on tourist's overview about Lugu Lake**



According to the survey statistics, the intention of payment by tourists on protection of the ecological environment of Lugu Lake is an average 22 Yuan, much higher than the current three Yuan for the protection covered in the admission ticket to the Lugu Lake scenic areas.

The survey also shows that intention of payment by tourists for admission tickets for

Lugu Lake scenic areas is 58 Yuan.

The intention of payment by tourists for protection of Mosuo traditional culture is 22 Yuan, which is the same as the payment intention on protection of ecological environment. This indicates that tourists attach the same importance to the protection of the Mosuo traditional culture as that of protection of ecological environment. This also coincides the survey findings that the scenery and local folkways are the main parts to attract tourists to Lugu Lake areas.

## **5. Conclusion and prospect**

### **5.1 Main factors influence the eco-environment of Lugu Lake**

The ecological environment in Lugu Lake basin is fragile. The lake supply coefficient is only 3.54 and the variational water reserve is only 5.6% of the lake content. The lake's natural ability to renew itself is weak so that once contaminated, it is difficult to recover. However, the natural resources in the basin suffer various damages now, such as many trees have been felled and mountains have been reclaimed in partial areas, a large number of visitors bring lots of rubbish, and so on. Thus the regional environment and water body are suffering from various degrees of impact and pollution.

Lugu Lake basin's tourism resources and environment are also fragile. As its major landscape resources are lake water, forest vegetation and the Mosuo nationality's culture, Lugu Lake's regional tourism resources include natural ecosystem and folk culture system. But the resources and environment above are vulnerable: the lake water is easy to be polluted; in the forest logging for many years has resulted in soil erosion. As the Mosuo population is too small and they dwell dispersively, their traditional culture and social customs are highly impacted, diluted, and even disappear.

The soil erosion in Lugu Lake basin should arouse much attention. Generally, the current erosion is micro to mild degree erosion and the erosion modulus is  $200-300\text{t}/\text{km}^2 \cdot \text{a}$ . In partial regions such as the upriver areas of Big Fish Dam, due to artificial unreasonable exploitation and reclamation, water and soil erosion is serious, growing into mudslide disasters. In partial zones of Lugu Lake southwest slope, water and soil erosion is also severe and in recent years it has been well controlled.

### **5.2 Brief result**

See the Table 17 for the result of the reckoned value of the services of the ecosystems of Lugu Lake areas.

**Table 17 Evaluation result of Lugu Lake basin ecosystem services**

Function	Sub-categories	Value ( $10^4$ Yuan/a)	Account for Total Value
Production Supply	Product of Farming, Forestry, Animal Husbandry and Fishery	1148.9	0.64%
	Forest Product	5336.4	3.00%
	Water Resource Product	47.7	0.03%
	Subtotal	6533	3.67%
Regulation	Soil Conservation	34	0.02%
	Water Resource Self-restraint	1386	0.78%
	CO <sub>2</sub> Absorption	1830	1.03%
	SO <sub>2</sub> Holding and Dust Detained	110	0.06%
	Waste Degradation, Nutrient Recession	128	0.07%
	N/P Water Purification	21	0.01%
	Nutrient Circulation	310	0.17%
	Water Distribution and Storage	154000	86.61%
	Subtotal	157819	88.76%
Support	Releasing O <sub>2</sub>	6678	3.76%
	Maintaining Biology Diversity	4356	2.45%
	Subtotal	11034	6.21%
Culture and Tourism	Culture	1320	0.74%
	Tourism	1100	0.62%
	Subtotal	2420	1.36%

The total value of the services of the ecosystems in the areas is  $17.78 \times 10^8$  Yuan/year, of which, the functional value by providing products is  $6553 \times 10^8$  Yuan/year, accounting for 3.67% of the total; the value of regulating function is  $15.78 \times 10^8$  Yuan/year, accounting for 88.76% of the total; the value of supporting function is

$1.10 \times 10^8$  Yuan/year, 6.21% of the total; and the value of cultural and tourism functions,  $2,420 \times 10^4$  Yuan/year, accounting for 1.36% of the total.

For Lugu Lake areas, the value of the regulating function mainly demonstrates in the value of function of water regulating and storage. The functional value of water regulating and storage of Lugu Lake takes up 86.61% of the total service value of the ecosystems in the areas, which tallies with the water system of Lugu Lake valley. So, protection of the water system of Lugu Lake is of great significance to the sustainable development of the areas.

The total income of the primary and tertiary industries in Lugu Lake areas was 15.14 million Yuan in 2000, only accounting for 4.0% of the service value of the ecosystems in the areas. The combined tourism income in Lugu Lake scenic areas reached 126.8 million Yuan in 2004, 7.1% of the service value of the local ecosystem.

Due to the insufficient materials and data, the present evaluation methods of the services of the ecosystems are not mature, and the value of some of the services is hardly to be calculated. For example, there has been no evaluation made in many aspects in Lugu Lake areas such as the C accumulation of the grassland ecosystem, maintaining biological diversification, guarding against biological damage of various ecosystems, value of gene resources, value of heritages of nature, human being and cultural scenic spots. The Table 17 only shows the minimum value of service functions of the ecosystems in Lugu Lake areas with the current limited evaluation methods, and the value of service by the ecosystems in the areas will exceed the total value of the evaluation.

## **5.3 Strategies and countermeasures**

### **5.3.1 Enhancement of the protection planning of the scenic areas**

On the basis of the principle "putting prevention first, combining prevention and treatments, comprehensive protection, sustainable development, sustainable use", and

in accordance with national laws and regulations, we should make a scientific plan for the unique humanistic resources whose main body is Mosuo culture and the natural ecosystem which mainly contains the lake water and biological resources in Lugu Lake region. After integrating the protection of region-wide ecological environment and the protection of scenic tourist areas, we should pay more attention to planning for the control of Lugu Lake water pollution and preservation of the Mosuo culture. Moreover, we should develop grading protection measures to prevent from disorderly development and destructive construction tourism area.

The protection of Lugu Lake scenic areas should include the protection of local ethnic villages, the protection of natural resources and overall environmental protection of scenic landscapes. According to the request of the management of scenic areas, we should put the protection keystone and measures of the core beauty spot forward aiming at its scope in the scenic areas. In the process of building and managing the scenic areas, we must comply with corresponding protection rules.

The core beauty spots in Lugu Lake scenic areas include Mosuo villages conservation areas, grass-ocean wetland ecological conservation areas, scenic cultivating areas and the Lugu Lake folk customs scene zone belonging to the primal and secondary protection view area, the pilgrimage area in Gemu Hill's highest peak, Zuan Dong mountain kop dell view area.

To the characteristics of the core view area, the emphasis of the planning is keeping and continuing the race culture, protecting the natural landscape special features and growing the sound ecosystem environment. The protections of the race culture include not only the protection to the existing small village buildings, but also maintaining and extending its non-material culture, and studying the homologous countermeasures. The protection of natural landscape features is not limited to the mere protection of the status quo of the good natural landscape, but also focus on the utilization of its resources and the reduction of the constructive destruction. The cultivation of the

ecological environment involves not purely reforestation, but also promoting the structural adjustment of regional agriculture and economic development according to certain production, and fundamentally changing the environmental damage owing to agricultural production and the backward way of life.

### **5.3.2 The protection of the Mosuo nationality cultural resources**

The Mosuo nationality culture is the rare resource and soul of Lugu Lake tourism area so that the effective protection of the Mosuo culture is the guarantee of sustained development and prosperity in this area. But the protection is not closed protection or giving up the development, and further more, the protection and development must be equal in order to promote the protection with the exploitation and to get development from the protection.

(1) The necessary local laws and regulations should be expeditiously enacted in order to protect the Mosuo culture effectively. For example, we should restrict the immigration and the disintegration of the matriarchal family household, regularize and maintain the "Axia" marriage patterns, and prevent the variation and disintegration of Mosuo matriarchal clan family and marriage patterns under the impact of external culture.

(2) The Mosuo cultural conservation village (region) should be established so that the highly valuable matriarchal system will be protected and preserved originally in the village communities and the ecological environment. And they can keep up their normal development and continuance. The natural environment, living environment, residential areas, courtyard, village patterns, folk customs and traditional lifestyles in these villages must be strictly maintained and integrally preserved. The subsequent buildings should not be incompatible with the original features to ensure the integrity of their environment and the authenticity of their living areas. At the same time, the living conditions of villagers should be improved through the improvement of the infrastructure. In addition, in the above villages, "Mosuo folk cultural sightseeing



village" can be selectively opened. Moderate and restrained tourism activities can be launched in the village, but the principle "separation of tour and living" should be implemented and the construction of tourism facilities should be strictly limited in the village.

(3) The research on protection and development of Mosuo nationality culture should be strengthened. Beside of systematic collection and collation of the Mosuo cultural relevant information (including tangible culture and intangible culture), accreditation and academic research are indispensable. The protection and development of Mosuo culture, such as family structure and marriage patterns, "Daba" primitive religion, song and dance art, folk festivals, architecture, folk crafts, and so on, should be organized and implemented as well. The Mosuo people should undertake the traditional cultural education so as to be able to become Mosuo cultural descendant.

### **5.3.3 Intensifying protection of the ecological environment**

Lugu Lake regional ecological environment is fragile, once damaged it will be difficult to be resumed. With the increase of visitors' number, the problem of Lugu Lake regional ecological environment has been gradually exposed. For instance, Lugu Lake basin pollution has been increased, the lake suffering a heavy metal pollution, living garbage especially some hardly degradable materials such as plastic, foam, etc is increasing in the lakeshore, and the output of unique fish —— the Abdomen Fissured Fish in Lugu Lake has sharp declined and it's even on the brink of extinction, and so on. They are all problems due to tourism development. In the conditions that the tourism still needs appropriate development, intensifying our protection of the ecological environment has become more and more important.

### **5.3.4 Strengthening whole cooperation of Lugu Lake region**

Lugu Lake belongs to Yunnan and Sichuan provinces. The region's economical social development as well as the exploitation of tourism resources is urgently needed provinces' close cooperation. For example, the arrangement of tourist facilities should

balance the interests of the two provinces, the project should be in conjunction with the respective features of different tour landscapes, and in the aspect of resources protection the responsibility of the two sides should be clearly definitized. Planning should be shared with the two places as the technical requirements when they build scenic areas and develop the tourism.

In the process Lugu Lake regional sustainable development, in addition to cooperation of the two provinces, mutual cooperation and coordination among the villages of inside region and all races are required, too. In this region, because of the various degrees of exploitation of tourism resources in different areas, the socio-economy in different villages and various nationalities develop inconsistently. A number of villages are rich, while some others are very poor. The lack of socio-economic harmonious development, to some extent, will bring inconsistency among these villages, and even inter-ethnic conflicts. Therefore, in the process of the resources' exploitation, it is necessary to consider the coordinate development of different areas.

#### **5.4 Prospect research of EVES**

This research has summarized the ecological economics normal form which should be followed in research EVES, on the basis of reviewing relevant theory and case, probe into and instance analysis through the theory of this paper, we can study tentatively on EVES as following:

First, ecosystem services evaluation broadly enlarged the conception of price and cost but not all market substitution methods can be taken as real market methods. What we need for ecosystem services evaluation is not only to prove the importance but also to emphasize its public or collective shortage and rarity. Generally, ordinary market value for goods or services is estimated according to its rarity for individuals. Economic valuation for ecosystem services can be used to explore the difference between individual and public costs and benefits, then to design policies and institutions to reduce their difference.

Second, sustainable natural resource exploitation require comprehensive and dynamic evaluation of ecosystems and their services, and partial and static evaluation is also useful. In order to evaluate ecosystem services and their relations with human society, all kinds of evaluation methods have been developed. One series of methods were developed from the view angle of physical integration of complex ecosystem. Environment, economy and society cross each other and make a big net in which a little knot change will make the whole net change. Some methods were designed to search the unit that can reveal the fundamental characters and make arbitrary parts of the system can be calculated with the unit. In other words, global research trend needs holistic views of ecosystem services evaluation but reductive evaluation of ecosystem services made it possible to insert natural factors into regional and local decision. Scientific research and management for ecosystem hiberarchies need both applied and should be across in one research procedure.

Third, in order to promote the capability improvement of regional ecosystem services, both supply and demand of specific regional ecosystem services should be considered. In this paper, the supply of ecosystem services were classified into some kinds of ecosystems and then into some specific kinds, but their shadow price index were chosen according to economic and social characteristics of South China.

Fourth, holistic and reductive research angle of ecosystem services evaluation can promote each other. Reductive research focuses on the benefits and costs of individual then little groups the larger collections, which would make individual decision makers (individual person, individual corporation, individual organization, individual local government, etc.) broaden their view angles and consider ecological factors that maybe important for their future situation. These considerations would make those individuals directly or indirectly bargain on ecosystem services changes. Partly and potential market of ecosystem services make it possible for further research of ecosystem services market substitution which leads to more general assessment.

Fifth, while ecosystem functions and services are divided into more and more specific kind, evaluation of ecosystem services can include more and more eco-economic chain effects, so it is possible to establish integrative assess models for complex ecosystems. However, it will be a long and hard work in which two difficulties must be resolved: physical research accumulation and macro benefits abutment with micro benefits. Different methods designed from different disciplinary angles will permeate each other and establish a comparable index systems, etc.

There are a lot of related topics which could be further studied. One suggested further study for the project is to determine the impact of increase of tourist. More accurate projections of future lake water balance and how lake functions react to these changes is one of the further studies in technical level.

With respect to environmental economics in China, future studies include: How environmental valuation methods are applied in China? How Economic Evaluation of ecosystem methods would be carried out in China? Enlarged economic evaluation of ecosystem services may be helpful for relative stakeholders who will take better and more public rational choices. Then researches can learn and summary more comprehensively from the more practices.

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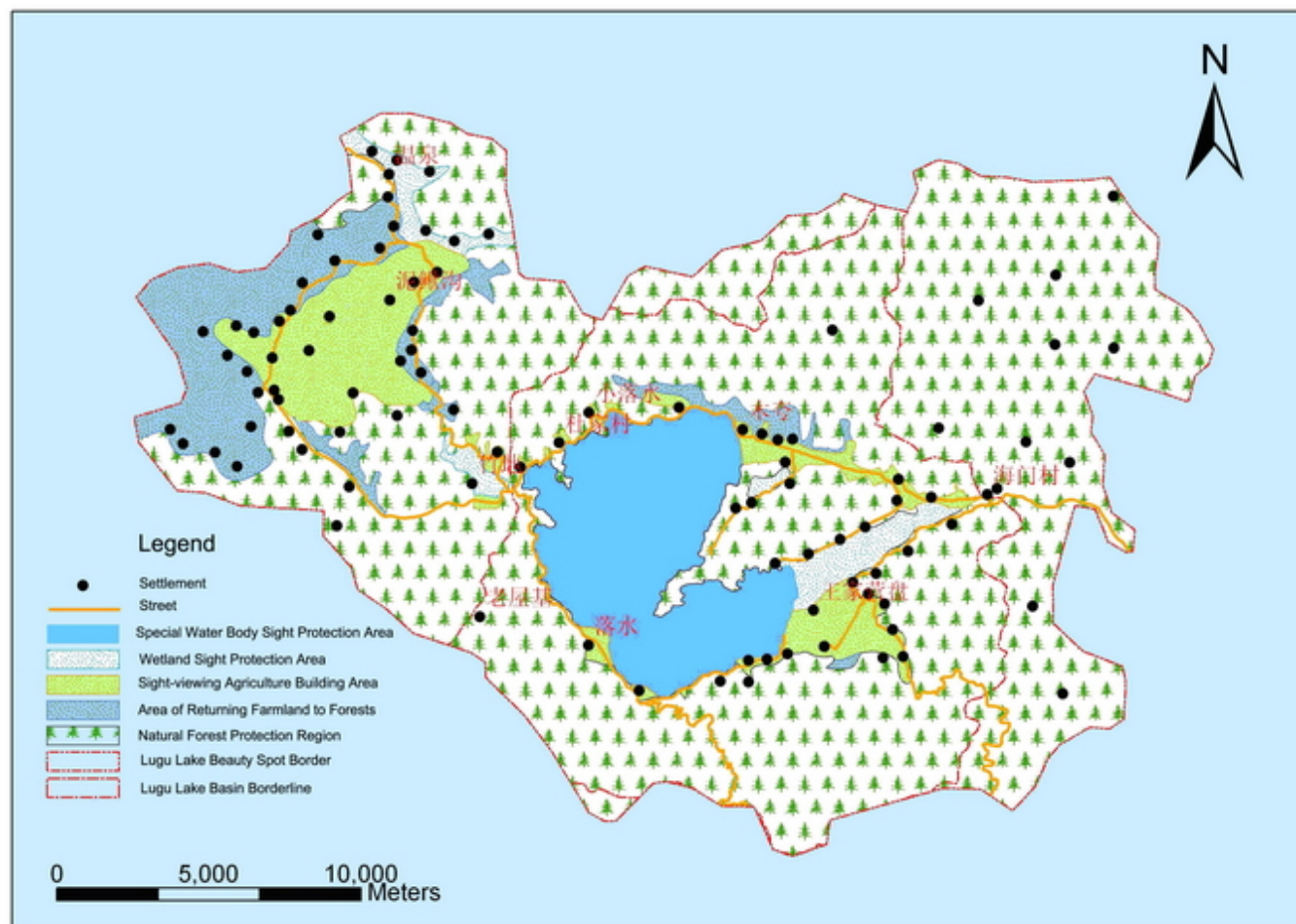


## Appendix

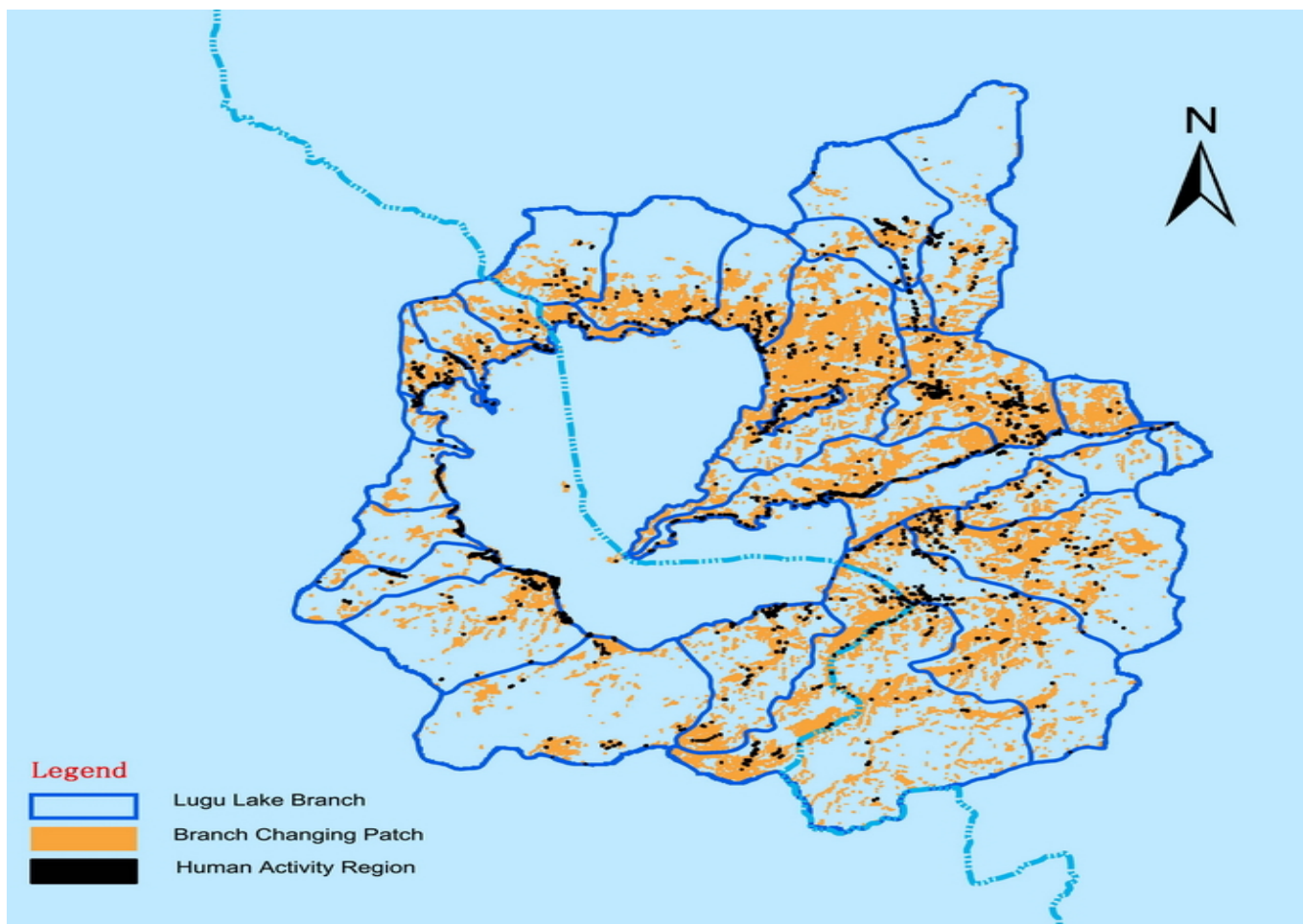
## Appendix 1 General Layout of Lugu Lake



## Appendix2 Function Subarea Map of Lugu Lake Landscape Ecological Building

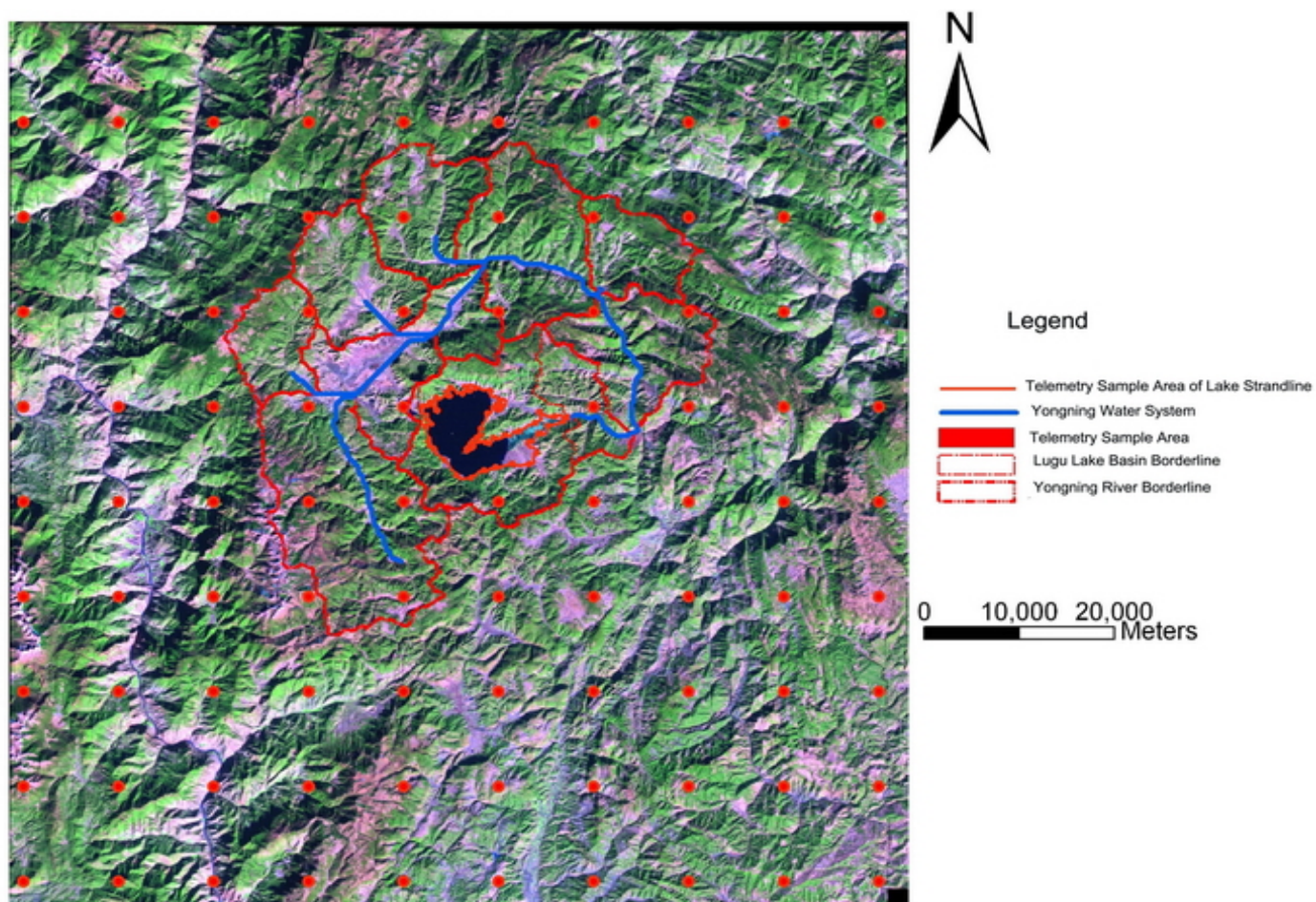


### Appendix 3 Relationship between Human Activity and Ecosystem Changing Patch



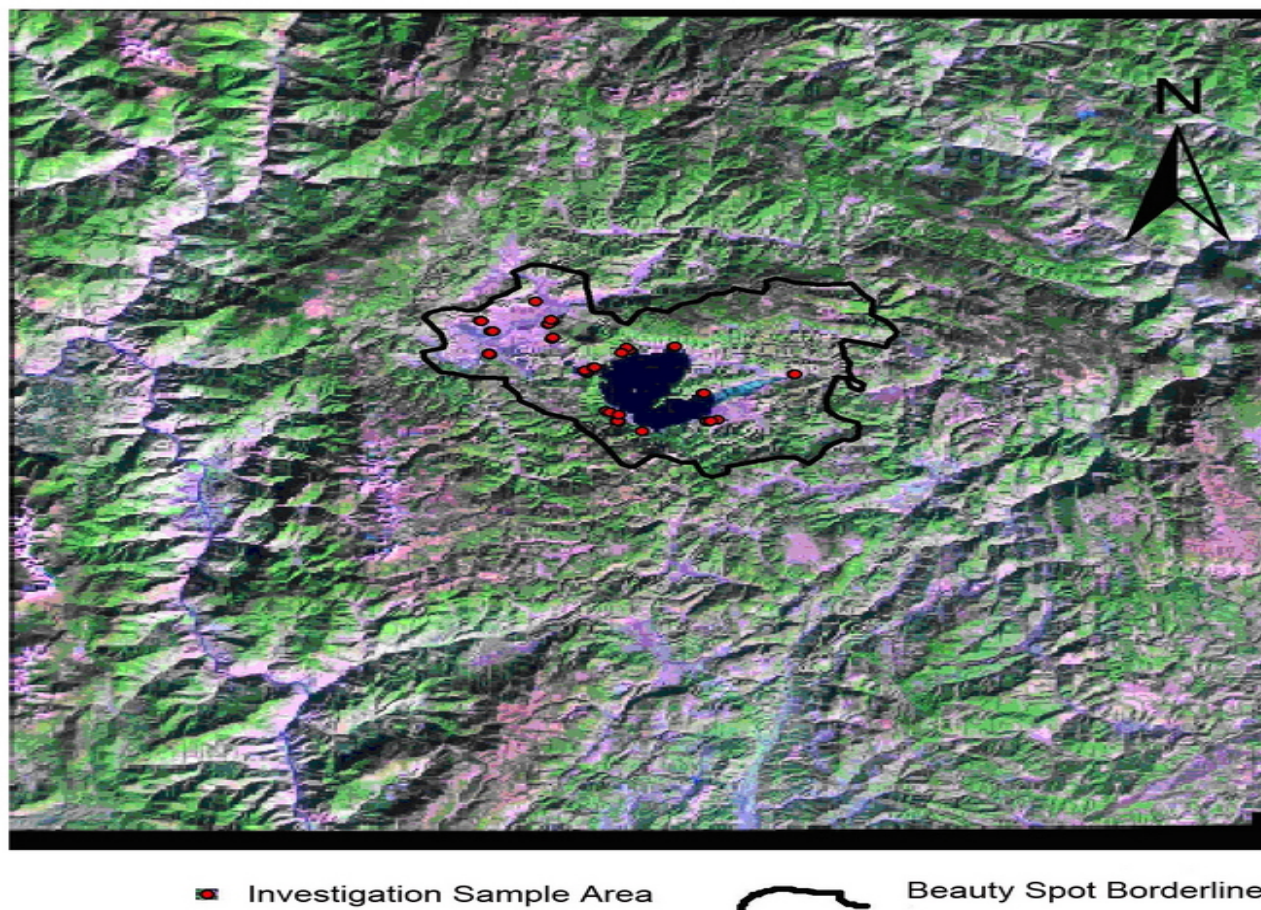


#### Appendix 4 Ecosystem remote sensing and monitoring sample area distribution in Lugu Lake area



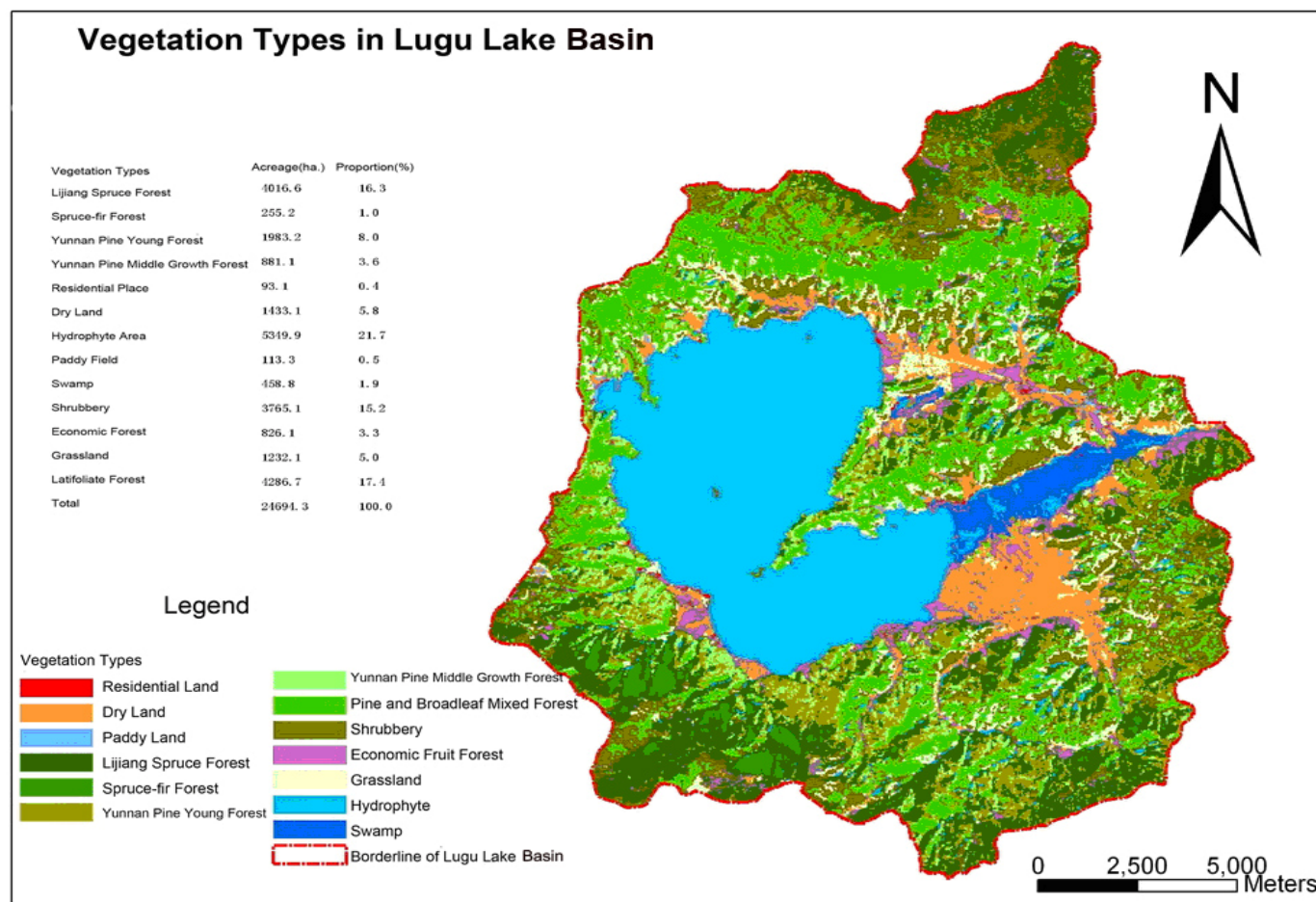
## Appendix 5 Sketch map of folded research region of Lugu Lake boundary and ecosystem investigation sample place

(Note: Satellite image is the wave band combination of TM (R5, G4, B3))

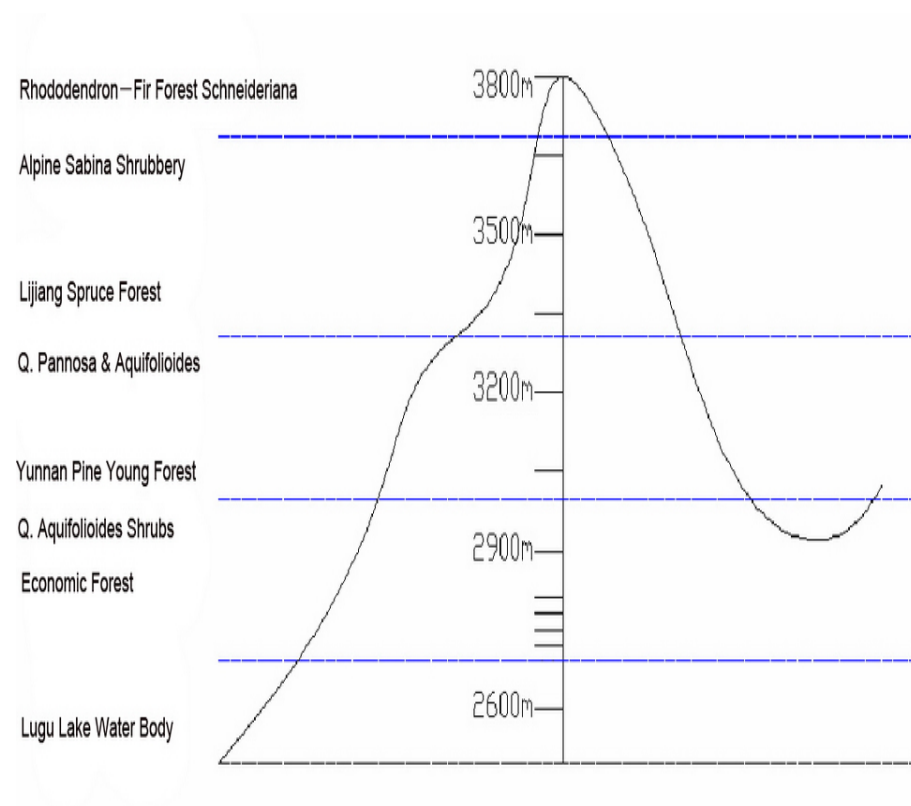




## Appendix 6 Vegetation Types in Lugu Lake basin



## Appendix 7 Vertical distributed Forest and Vegetation in Lugu Lake Basin



## Appendix 8 Land uses distribution in Lugu Lake Basin (1995/2005)

